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The ADVANCEMENT OF SCIENCE

Vol. IV, No. 16

Penicillin and other Antibiotics
BY SIR HOWARD FLOREY, F.R.S.

The Sense of Smell
BY PROF. E. D. ADRIAN, O.M., F.R.S.

Petroleum To-day and To-morrow
BY DR. KIRTLEY F. MATHER

Camouflage
BY DR. H. B. COTT

Scottish Forestry
BY MR. A. H. GOSLING

Can Britain Feed Herself?
BY THE RT. HON. WALTER ELLIOT, F.R.S.

Climate and Efficiency
BY PROF. H. C. BAZETT

Education of the Man of Science
REPORT OF A DISCUSSION

Operational Research in War and Peace
REPORT OF A DISCUSSION

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THE ADVANCEMENT OF SCIENCE

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SWORDS INTO PLOUGHSHARES

Report of the Annual Meeting at Dundee, 1947

'An outstanding scientific event' is a description applied to the Annual Meeting of the British Association in a pamphlet outlining the functions which the Association has performed during the 116 years since it was founded. Whether this description would be true of the first post-war meeting was never a matter of doubt in the minds of those who were in a position to know and to understand the unique position held by the Association; but by the end of the meeting, which was held in Dundee from August 27 to September 3, 1947, it was obvious to over three thousand people who were present, and to others who read reports in the press and listened to contemporary broadcasts, that the first full Annual Meeting for eight years justified the words by the President who described it as 'a resounding success' at a final press conference.

Many months before the proceedings opened it was clear that this could not be an ordinary meeting. The Association had had some experience of starting up again after a world war and had successfully overcome the difficulties then obtaining. On this occasion, however, the interruption to continuous activity had been longer and conditions were substantially different: indeed it was practically necessary to refound the Association. Also, science had played in the second world war a much greater part than in the first world war, and there was much more to report. Moreover, the strain on the economic resources of this country had been so great and the aftermath of war had produced so many serious international problems, that there was considerable scope for public examination of the part which Science could be expected to play in recovery.

As it so happened, the meeting opened shortly after the Government had announced the full severity of the economic crisis in Great Britain. This added point to the decision of the Council, made nearly a year ahead, that emphasis should be given in the programme to the positive contribution of science to human progress, and provided an additional sense of urgency in discussion on the peace-time role of men of science.

The Presidential Address by Sir Henry Dale on 'Science in War and Peace' and the Addresses of the thirteen Sectional Presidents have already been published in full in *The Advancement of Science* (No. 15) and summaries of them have appeared in *Nature*; other addresses are included in this issue and further reports on Sectional Transactions will appear in two later numbers. The purpose of the present note is to review the meeting as a whole and, as the scientific programme included contributions by at least 260 speakers on nearly as many subjects, it is obvious that little more than general and random impressions can be given.

It may be recalled that the last full meeting of the Association began in Dundee on the eve of war in 1939, and was abandoned on the third day. It was a splendid act of generosity on the part of Dundee and district to offer hospitality to the Association on this occasion. The loyal and energetic support of all who were responsible for local arrangements assured the Association of a warm welcome to Tayside, and the warmth of this welcome was symbolised on the opening day of the meeting when the freedom of the City was conferred on Sir Henry Dale. This was only the second occasion in the history of the Association when the President had been so honoured in his year of office, the first being in 1867 when the Duke of Buccleuch was made a freeman of the place of meeting—again Dundee.

At an impressive and dignified public ceremony in the Caird Hall, the first of its kind since 1934, the President was welcomed in his own right as an eminent scientist, as the reigning President of the Association, and as the representative of men of science who had spared no effort to achieve final victory. In giving thanks for the honour bestowed on him and on science, the President said he appreciated the freedom of Dundee all the more since it was given in a 'district which could claim pre-eminence on account of the staunchness with which its sons had stood and fought in defence of its freedom through blood-stained centuries. The British Association has closely watched the development of

our modern civilisation into this scientific era, has shared in the general pride of this country in the achievements of British scientists during the war, will watch, with jealous anxiety for the achievement by science, as by every other sane and useful activity of mankind, of the full freedom which victory should have ensured, and will look to the use and the promotion of science with wise vision to aid the recovery of a battered world and the renewal of its progress to a fuller happiness, a more stable peace and a deeper culture.'

The freedom ceremony was followed by a luncheon in the City Chambers when the Corporation entertained 100 guests. After lunch, while visiting members of the Association continued to arrive in Dundee and to report at the Reception Room in the Training College, meetings of the Committees of Sections, the Council and the General Committee, were held. From the afternoon's discussion two items of importance emerged.

The General Committee unanimously elected as President for 1948 Sir Henry Tizard, K.C.B., F.R.S., scientific adviser-in-chief to the Government ; and the Council appointed a committee, with the President-elect as chairman, to advise on any ways in which the British Association could assist the country in the economic crisis.

At the meeting of the General Committee, Sir Henry Dale presented to Dr. O. J. R. Howarth, Secretary of the Association from 1909 to 1946, his portrait in oils as a token of esteem from members of the Association. The portrait, which was painted by Professor Robin Darwin, great-grandson of Charles Darwin, was subsequently displayed in the Reception Room.

The Meeting was formally opened in the Caird Hall in the evening when Lord Provost Powrie welcomed the Association to Dundee and Sir Henry Dale delivered his Inaugural Address on Science in War and Peace. In the course of his address the President surveyed some of the major achievements of men of science during the war and gave examples of the triumphs of science in the service of war which would be of lasting value in the service of peace. In a general survey of the position of science to-day Sir Henry stressed, as he had so eloquently done before, both in this country and in North America, the imperative need for freedom in scientific research. He said that science found itself facing a situation in which hope and frustration contended. The need to make the world safe and the delay of agreement on the means of doing so clogged the wheels of science when they should be turning freely for the enrichment of knowledge and of human life. Men of science were facing this situation with complete loyalty to all their obligations, but with resolute watchfulness against any encroachment, on activities proper to peace, of a secrecy which had been accepted as necessary in war. He hoped that scientists of the near future would be able to grow up, as their predecessors did, in an atmosphere of scientific freedom.

On the role of science in peace, the President said he thought it was necessary to take a long-range view and declared his belief that the first care should be the extension of fundamental knowledge, unconstrained by any practical objective, the building up of our capital of scientific knowledge without which, in the long run, the well springs of discovery and inventiveness would dry up. In a postscript in his address as prepared for the printer, and which is published here (see page 280) he urged his listeners not to be over-optimistic about the short-term contribution which scientists could make towards recovery.

At the close of his address the President launched an appeal for a Development Fund of £100,000 to enable the Association to promote the advancement of Science, by all the means in its power.

In felicitous terms Sir James Irvine, Vice-Chancellor of the University of St. Andrews, proposed a vote of thanks to the President : and the President announced that registrations up to the end of the first day numbered 3,000 precisely. In later days the numbers swelled to 3,236, including 1,730 local registrations, the latter figure being a record for meetings held in the United Kingdom. The membership included more than 50 visitors from overseas, of whom 17 were guests of the Association.

In brilliant weather, which continued unbroken throughout the week of the meeting, the sectional programmes opened on Thursday morning, and except for the week-end, thirteen sections met simultaneously or in joint session each morning, and occasionally in the afternoon, till midday on September 3. In spite of efforts to stagger presidential addresses and other items of major importance it had been impossible to relieve members of the responsibility of deciding which of two or more sessions they should attend, and in many cases ' room full ' notices greeted those who were not early in their places ; but there was sufficient of interest available to all at any given time and a general atmosphere of purposeful activity and bonhomie was quickly apparent.

The Presidential Addresses to the Sections were delivered on the mornings of Thursday, Friday and Monday, and naturally attracted large audiences. Scant justice can be done to them in a review of this nature, but reference may be made to them briefly as follows.

Sir Edward Appleton, speaking on ' Earth, Stars and Radio ' showed how the work of radio physicists was related to that of geophysicists, meteorologists, solar physicists and astronomers. Himself a pioneer observer of the reflection of radio waves from the upper atomsphere, he traced the rapid development of radiolocation and radar and described the prospect of using such methods for studying the bursts of radiations from the sun and the stars, and the effects of these radiations on the atmosphere of the earth and, in particular, their effects on our weather.

Dr. J. L. Simonsen spoke on ' Science in the Colonies.' He forecast that cane sugar, which was the organic chemical produced in a pure state on the largest scale in the world, would be regarded in future not only as a food but as a raw material suitable for use in several branches of the chemical industry. He referred to a number of important scientific developments in the Colonies, for example a projected microbiological research institute in Trinidad. In stressing the importance of scientific efforts in the Colonies he regarded the health of colonial peoples as a prime consideration. In this connection new synthetic insecticides had an important part to play in the prevention both of food waste and insect-borne disease.

Dr. M. Macgregor gave an address on ' Geology in the Development of the Coalfields.' In reference to the geological implications of nationalisation of the mines he expressed the view that this development, which should lead to more immediate and complete availability of information than was previously possible, offered opportunities to geologists not only of service to the country but also for the advancement of Science. He cast some doubt on available statistics of world coal reserves and pointed to the need for a new study.

In his address on ' Zoologists in War and Peace,' Dr. Edward Hindle gave some examples of the value of the work of zoologists to the community, and described the benefits to be derived by individuals from a training in biology, benefits which enabled them to tackle successfully a variety of work not directly connected with zoology. He reported that zoologists had played an important part in maintaining food supplies by the control of animal and insect pests and gave a warning that large enterprises such as the East African Ground Nut Scheme could be complete failures if adequate biological advice were not obtained.

Professor Eva Taylor, in an address on ' Geography in War and Peace,' described some of the war work undertaken by geographers in Government departments and in the intelligence branches of the various Commands, from which geography had emerged with an increase in prestige and with techniques which could be applied with advantage to peace-time problems. At the end of her address she maintained that more attention must be paid to maps and globes if the recognition of the regional differentiation within the framework of the earth was to become, as she thought it should, a familiar part of the mental background of every thinking person.

In his address on ' The Economic Outlook ' Professor Dennis Robertson summed up the Government's Economic Survey and the Industrial Charter of the Opposition, and analysed the views of some authorities on economic planning. In his view it was too early to give up hope of working a passage back to a state of affairs in which we could keep our heads above water without the aid of a perpetual plan, but years of low-brow talk about production for use and not for profit and fewer years of highbrow talk about the humbug of finance and about investment breeding its own saving, and left a formidable web to unwind. He thought it would be necessary to beat a certain amount of retreat in the matter of subsidised consumption and that planners should ask themselves whether first things could come first unless the individual developed the will to put and keep them first.

Sir William Halcrow covered a very wide field in his address on ' Progress in Modern Engineering ' and described recent developments in civil, mechanical and electrical engineering. He was able to report impressive progress in many directions and spoke with special authority of harbour works and hydro-electric schemes with which he has been closely associated. Discussing power transmission he forecast that the gas turbine would supersede the internal combustion engine for certain uses and would eventually challenge the steam turbine.

Professor Daryll Forde, who spoke on ' The Anthropological Approach in Social Science.' discussed the processes and factors involved in the development of unilineal kin groups, the scientific value of ethnographic data obtained by field investigation, and the importance of analysis and comparisons in attempting to reach understanding of any problems of social structure.

In her address on ' Physiology and the Community,' Professor Winifred Cullis described the work of physiologists in maintaining the health of the community with particular reference to balanced diets and therapeutic drugs. She stressed the desirability of an understanding by the public of the principles of healthy living derived from sound knowledge of the way in which the healthy body functioned. In this connection she discussed the merits of films and broadcasts and emphasised the need for more competent teachers of physiology.

' Man's Adaptability ' was the subject of Dr. S. J. F. Philpott's address to psychologists. He discussed some of the practical problems which face those concerned with vocational guidance (doing the best for the individual) and selection (ensuring that a stream of good material is directed into the proper quarters) ; he described how some of those problems were tackled in the Army in war-time and the lessons which, then learned, should help in peace. In regard to tests of ability, he said that their interpretation too often ignored man's versatility. ' Each man in his time plays many parts ' and tests should determine all-round ability rather than point to particular narrow aptitudes. This was particularly important when testing the abilities and needs of children of whom millions would have to be examined under the new Education Act.

At the beginning of his address on ' The History of Plant Form,' Dr. Hamshaw Thomas asked whether, in an age when evolution was accepted as a fact, it could truthfully be said that we knew more about the history of plants than was known in Darwin's day. He then discussed some of the reasons why the interpretation of the fossil record of plant development had made so little progress compared with the interpretation of other fossil records. He advocated an objective study of plant form in the fragmentary records in rocks of various ages and the throwing overboard of deductive reasoning in favour of precise observation. He described his theory of the evolution of flowering plants and stressed the importance of obtaining further evidence of the development of plant form.

As the meeting of the Association was the first since it had been decided that all children should be given secondary education, it was appropriate that the President of Section L, Miss Lynda Grier, should choose ' The Evolution of Secondary Education in England,' in which she reviewed some of the major causes which had led to so revolutionary a decision.

Dr. W. G. Ogg, speaking on ' Soils and Health ' devoted the first part of his address to a review of knowledge of ' trace elements,' those chemicals of which very small quantities are vitally necessary for soil fertility. In the second half of his address he reviewed the scientific evidence in favour of synthetic fertilisers, and pressed home a vigorous

attack on those who opposed the use of ' artificials ' on health grounds. He said that important though the trace elements were, the deficiencies of major plant foods were more important still, and the propagation of beliefs about the detrimental effects of artificial fertilisers a disservice to world recovery in which the adequate supply of food was so large a factor.

In addition to the Presidential Addresses the Sectional Programmes contained the traditional variety of group discussions and individual papers with rather more than usual of the joint discussions between Sections. The separate papers, which are recorded in another section of this issue, are too numerous to mention in detail, but points of interest included a description by Professor Le Gros Clark of recent discoveries in South Africa of the remains of a creature which resembled man in its teeth, limbs and posture, but had an ape-like brain. He also reported the news, just received, of the discovery of the pelvis of one of those ' hominoidea ' ; an appreciation of the work of Lord Keynes by Mr. R. F. Harrod ; two papers by engineers on roof-top roads which stimulated active comment ; a description by Mr. J. H. Wilkinson of the National Physical Laboratory's plans for the A.C.E. (automatic computing engine) or ' electronic brain ' with which it was hoped to achieve a ' memory capacity ' of something like six thousand ten digit numbers with the use of a smaller number of valves than the 18,000 incorporated in the American machine E.N.I.A.C. ; Professors von Frisch's interpretation of the dance language of the bee ; the mechanical records of Professor Johnston Wallace, an American visitor, which showed that the dairy cow feeds no more than 8 out of 24 hours a day whatever the state of the pasture, and many other interesting and stimulating reports.

Of the discussions in and between Sections, one which attracted considerable interest was that on peace-time applications of nuclear fission in which Dr. J. D. Cockroft, Director of the Atomic Energy Station at Harwell announced that the first uranium atomic pile in Britain had just come into operation. In discussing the prospect of producing atomic power for peaceful uses, Dr. Cockroft was not able to give any optimistic forecast. He said that experimental power plants might be built within five years, and the production of power might become a practical possibility within the next ten years, and until further experience had been gained, the cost of nuclear power could not be predicted with any high degree of accuracy. Professor Otto Frisch, who, with his aunt, Dr. Lise Meitner, was responsible for important pioneer work on nuclear fission, spoke on the fission pile as a research instrument, and Mr. W. G. Marley, who works at Harwell, read a paper on the production of radio-active isotopes from the new pile. The subject of tracer elements, stable as well as radio-active, was discussed later in the meeting at a joint session of the Chemistry and Physiology Sections. The papers included one on bio-chemical applications of radio-active isotopes by Dr. A. S. Macfarlane, who reported that radio-active phosphorus had found a wider application than any other radio-active element on account of its convenient half life, its suitable radiation characteristics, and its wide distribution in the animal body ; it was adding new knowledge on the biochemistry of the living cell.

Another meeting which created much interest was a discussion on the applications of radio to astronomy and meteorology, which followed Sir Edward Appleton's presidential address, and in which several young and high ranking experts read papers, in one of which an apparently new method of auroral observation was described.

As a topic of considerable current interest coal was given an important place in the programme ; the Geology Section had a discussion following Dr. Macgregor's address, in which one speaker, Dr. G. M. Lees, spoke on the prospects of discovering new coalfields in this country ; the Physics Section discussed coal as a source of heat and power and the discussion produced much evidence that considerable quantities of this precious commodity were still being wasted by inefficient methods and equipment ; the Engineering Section received a paper on coal cutting machinery and visited a colliery ; nor was the collier overlooked, for in a session on 'Man and the Machine ' in which physiologists, psychologists and physical anthropologists took part, attention was drawn to the failure to apply scientific knowledge for the improvement of working conditions in the mines.

Of the many other interesting and important subjects which were discussed it is possible to make reference only to a few. Food and health were naturally subjects of great significance. As regards the production of food, the Rt. Hon. Walter Elliot opened a discussion on the question ' Could and should Britain try to feed herself? He said that expansion of home production was imperative but doubted whether Britain could ever hope to become self-sufficient ; another speaker, however, thought that Britain would feed herself if sufficient machinery, fertilisers and feeding stuffs were forthcoming. As regards prevention of disease in man, plants and animals, and the waste of foodstuffs, control of plant and animal pests is of great importance and discussion on insecticides and parasitology, were of topical interest. In a discussion on antibiotics (including penicillin and streptomycin) Sir Alexander Fleming and other experts reviewed the present state of knowledge and future possibilities.

In a discussion of interest to several branches of science, and to non-scientists concerned with national and local problems of recovery and development, the need for a national atlas was advocated and a committee (one of 23 research committees later appointed by the Council after the meeting) was recommended to prepare a scheme for such an atlas.

The daily meetings of the Sections were supplemented by evening sessions of varied character, at all of which the meeting rooms were packed to capacity. On Friday, Dr. Kirtley F. Mather, Professor of Geology in Harvard, delivered the British American Association Exchange lecture on 'Petroleum To-day and To-morrow' (see page 292) The following evening, under the auspices of the Division for Social and International Relations of Science, Sir Robertson-Watt and six other speakers (see page 320) took part in a discussion on ' Operational Research in War and Peace ' in which the first public account was given of some of the brilliant work of scientists in that field, (including

material recently declassified as secret.) On the following Monday Dr. H. B. Cott gave an illustrated evening discourse on Camouflage (see page 300) and on the final Tuesday evening, the President and five other speakers, at an open meeting, discussed the important question of ' The Education of the Man of Science ' (see page 309).

As has been customary, lectures and addresses were arranged for audiences who were not members of the Association. Sir Robert Watson-Watt gave public lectures on radar at Brechin and Montrose; Mr. A. K. Longair, a member of the Atomic Scientists Association, spoke on atomic energy at Perth and Blairgowrie; Dr. W. T. Astbury gave lectures on Textiles and Plastics at Forfar and Arbroath; illustrated lectures were given at St. Andrews by Mr. R. M. Adam on National Parks, and at Cupar by Dr. Frank Darling on seals. Lectures to children were given by Professor H. Hartridge on colour (on two successive days to different groups of children) and by Sir Richard Paget on sign language; and Miss Mary Field exhibited new films for children at a matinée performance.

Individual and private hospitality accorded to members of the Association was supplemented in many ways on a corporate scale. All members were elected honorary members of University College Students' Union for the period of the meeting, luncheons and other receptions were arranged by the Rotary Club, the Federation of University Women, the Soroptomist Club, the Business Men's Club and other organisations; members were received at garden parties by the University College, the Earl of Strathmore, the Dowager Countess of Airlie and Sir John Phin; civic functions included a brilliant reception for all members in the Caird Hall and a dinner, at which 250 prominent members of the Association were entertained: through the impromptu energies of some local students a dance was also arranged.

In addition to a multitude of services including the use of every student residence in St. Andrews and Dundee, the University of St. Andrews did the Association the honour of conferring degrees of Doctor of Laws, at an impressive ceremony in the Marryat Hall, on the following: Sir Edward Appleton, Sir Lawrence Bragg, Sir Henry Dale, Sir Alexander Fleming and Emeritus Professor A. R. Fulton.

In a district so rich in beauty, historical associations and points of scientific interest it was appropriate that there should be a large number of excursions. There were six general week-end excursions with places for 300 members and 27 sectional excursions with places for 1,340. The local organisers also arranged 25 visits to works in the district; and the industries of Dundee, old and new, combined to arrange a large and impressive exhibition of local products.

At the close of the meeting the General Committee passed with acclamation the following resolution:

> ' On behalf of all the Officers and Members of the British Association assembled in Dundee, the General Committee at the close of this meeting have resolved as follows:
>
> ' It was vital for the future of the Association that the first full post-war Meeting should be successful. By common consent the meeting in Dundee has been one of the happiest, most brilliant and most fruitful of many within the recollection of those present and the General Committee desire to place on record an expression of their deepest gratitude to the Lord Provost and Corporation of the City and all their officers, to the Principals and staffs of University College, Dundee, and United College, St. Andrews, to the Local General Committee, its Conveners and the members of their Sub-Committees, to all institutions for the use of their rooms and the willing service of their staffs, to those in Dundee and district who offered generous hospitality to parties and individuals, and to all others, of whom there are many, whose unfailing kindness has contributed to the comfort of visiting members.'

Following the meeting the Local Committee set aside £650 from the unexpended balance of the Local Fund, to be held as a Trust Fund from which annual grants would be made to support the work of local scientific societies whose objects were in sympathy with those of the Association.

ANNUAL MEETING, 1948

The Annual Meeting of the Association will be held at Brighton, September 8–15, 1948, under the Presidency of Sir Henry Tizard, K.C.B., F.R.S. Copies of the Preliminary Programme will be available during the first week in April and will be sent to members and associate members. Others may have it on application to the Secretary of the Association.

SCIENCE IN PEACE

By

Sir HENRY DALE

In his presidential address as delivered at Dundee on August 27, 1947, the President added a passage on the role of Science in the economic crisis. The following is a record of this addition to the address published in the Advancement of Science, No. 15, p. 151.

Since, under present conditions, it was necessary to send my Address to the printer many weeks ago, I ask ask your permission to interpose at this point, by way of foot-note or parenthesis, a few words on the relation of Science to the national economic predicament, which has since become a matter of general and anxious discussion.

As the end of the war came into view, there was much debate, in Parliament and elsewhere, of the need for a much greater and more effective use of Science and its methods by British industries. Even with all that Government aid had done to promote such a development since 1915, through the Department of Scientific and Industrial Research, a dangerous gap was still left between our national equipment in this respect and that of other countries, soon to be our competitors in the revival of world trade. It is safe to assume that the position had been also the subject of urgent representations, by scientists then in a position to offer confidential advice to the Government. The resulting appointment and eventual report of Sir Alan Barlow's Committee on scientific man-power are matters of common knowledge, as also the later appointment, also on that Committee's recommendation, of a standing Advisory Council of scientists and technologists, with Sir Henry Tizard as its permanent Chairman, to act as the regular advisers of the Cabinet on matters of high policy, concerned with the planning and promotion of the nation's scientific activities for all the purposes of peace. This new opportunity for expert scientific and technological knowledge to make its views known, at the highest level at which matters of state are discussed and decided, seemed to be an innovation of the greatest importance in our peace-time structure of government. And Sir Henry Tizard's appointment, at the same time, as Chairman also of the Defence Research Policy Committee, advising the Minister of Defence and the Chiefs of Staffs Committee, might suggest that the desirability of co-ordinating the Government's support of and requirements from Science for the combatant Services, with those intended to meet the needs of a nation at peace, had not been overlooked.

Some six months later our national economic emergency became clear and it would be natural for any Member of the Association to enquire whether anything could be done by a better use of Science to deal with the present crisis. On the face of it, the problem seems to be one primarily for discussion by our Section of Economics; Professor Robertson's Presidential Address to that Section on 'The Economic Outlook,' will have something to say about it, and the Section's Joint Discussion with that of Psychology, on 'Incentives in Industry,' may perhaps have some bearing on our present difficulties. It might further be urged, I think, that if, before the war, we in Britain had used Science adequately, the export of goods from our industries might have sufficed to pay for our imports, without calling upon earnings from foreign investments and carrier services to make good a deficit; that, under such conditions, the recovery of our balance of trade would have been much quicker and easier; and that, for the future at any rate now that two successive wars have liquidated the investments, which the energy and enterprise of our fathers had earned for us, we shall have to depend on our own efforts, which can only be effective if we use Science to the full.

Perhaps it is too obvious to require mention, that our past neglect of Science has thus contributed to our present plight; and I think that we can accord at least equal status, as a truism, to the statement, that a switching of industry from creating the means of wealth to providing the means of destruction, in two successive wars, has been a factor of prime importance in the origin of the crisis which we now have to encounter. It is, further, of the very nature of modern war, to divert industry not only from production to waste, but from a policy of normal prudence and economy to one in which a series of costly failures may be redeemed by a single triumph. And the application of Science to the service of war has similarly abnormal aims and criteria of success. While it may succeed in preventing certain costly war enterprises on which ignorance might have embarked, it may, for its own part, be the instigator of others as fantastically wasteful; and, in any case, war's assessment will judge Science on its contribution to a final victory, without counting the cost of its blunders and failures by the way.

We may take a proper pride, then, in the contribution made by our country's scientists to a victory in war which, at one time, seemed to hang so perilously in the balance, without supposing that their employment now, under generally similar conditions, would be likely to assist the nation to meet an economic emergency, of which the reckless waste entailed by war, even by the use of Science in war, has been a major cause.

We may sympathise with the sentiment which pleads for a full use of Science to extricate our country from its present economic difficulties, but I think that we may well pause before we accept the suggestion now being pressed upon our notice, that the use of Science in war has shown us the way to attain this end in peace. It does not seem to me that we can accept, as directly obvious, the suggestion that experience of the 'operational research' which estimated destructive effects and planned destructive policy in war, would qualify for guidance in the immeasurably more complicated and fundamentally different problems of reconstruction in peace. Again, while we may sympathise with the patriotic impulse behind it, I do not think that we can accept, as a remedy for the economic crisis, the further suggestion that 'Science can be fully mobilised and ably directed now as it was in the war.' Such a totalitarian use of Science by one nation, to prepare for a war of conquest, threatened the freedom of the world; to meet the threat, our own scientists gladly surrendered their own freedom and submitted to a like totalitarian control; but that necessity does not justify the assumption that a continued conscription of Science and surrender to authority by scientists is required by the present emergency, or that it would be effective in meeting it. These matters will, no doubt, be a subject of discussion from different angles in our sectional proceedings during the week. My own impression, at the moment, is of a certain prophetic character now achieved by words which, though they were written many weeks ago, I have only just read to you, in which I referred to 'a danger to Science from a tendency to transfer too easily and completely, to the activities of peace, the attitude to research and the traditions of its conduct which have been acquired during six years of war experience.'

PENICILLIN AND OTHER ANTIBIOTICS

By Sir Howard Florey, F.R.S.

Before an audience drawn from the members of the University of Cambridge and their friends in the Arts School on May 2, 1947, Sir Howard Florey delivered the Radford Mather lecture at the invitation of the Council of the British Association. In the lecture, which was illustrated by lantern slides, and of which the following is the text, he described the long history of the study of antibiosis, the direction in which research on antibiotics was proceeding, and the manner in which this research was carried out.

At the present time there is probably no country where scientific work is done in which the study of the phenomenon of antibiosis is not being vigorously pursued. It may be of interest if I try to give you a picture of the methods of study in this field, so that you may be better able to comprehend the direction of present-day researches and what may reasonably be expected to emerge from current work.

Antagonistic Micro-organisms

You have no doubt heard more than you care for about the wonders of penicillin, but it may not be generally recognised that penicillin is only one representative of a large number of substances which are now collectively known as antibiotics. It has been known for over seventy years that certain micro-organisms can live together for their mutual benefit—a state of symbiosis, and that they can prevent or disturb the growth of one another—antibiosis. The latter phenomenon is in some instances due to chemical substances produced by one micro-organism, which are antagonistic to the growth of others, and these substances are now commonly called antibiotics.

There is a vast population of micro-organisms in the soil, in decomposing organic matter and in the air, most of which are harmless to man though some cause serious diseases in plants. Amongst this population of different species of organisms a constant struggle for existence is waged, and it is possible that the chemical substances which some of them produce are useful to them in suppressing the growth of their rivals. There are broadly three types of micro-organism which have to be considered—the fungi, the bacteria, and the actinomycetes, which in complexity fall between the first two. It will give some idea of the number of species involved if I mention that it is estimated that there are 100,000 species of fungi alone. A quotation from Waksman [1] illustrates the same point with regard to the actinomycetes.

'If you will recall that certain soils contain as many as 1 to 10 million actinomycetes per gram, as determined by the plate method, that some soils, notably the arid and semi-alkaline soils, comprise a microbial population made up largely of these organisms, that as many as 10 to 50 per cent. of all the cultures of actinomycetes so far tested show some sort of antibacterial, antifungal, or antiviral effect, and that a large proportion, namely as many as 10 per cent. of the total, show a very high degree of activity—you will appreciate the importance of the subject under consideration.'

History of the First Observations

There has been a vast accumulation of information about antibiosis during the last seventy years from medical bacteriologists, mycologists and botanists. The phenomenon has been known since 1877, when Pasteur and Joubert first described the inhibitory or antibiotic action of air bacteria on the growth of anthrax bacilli, in other words, they found that certain air bacteria would stop the growth of anthrax bacilli. The phenomenon was well known to scientists by 1885 and suggestions for its use in medicine were even made by Pasteur himself. I can do no better, to give you an idea of how much was known over sixty years ago, than quote from Babès, a Roumanian working in Paris, who wrote in 1885 : [2]

'One of us has studied experimentally the way in which bacteria of a known species produce chemical substances or modify the culture medium in such a way as to harm bacteria of other species. If the study of the mutual antagonisms of bacteria were sufficiently far advanced, a disease caused by one bacterium could probably be treated by another.'

The first antibiotic to be used in medicine was produced by a bacterium now known as *Pseudomonas pyocyanea*. The material was prepared by Emmerich and Löw (1899) and

[1] Paper presented by S. A. Waksman at the Conference on Antibiotic Research held at Washington, D.C., on January 31 and February 1, 1947, under the auspices of the Antibiotics Study Section of the National Institute of Health.

[2] Babès, V., *J. de Connaissances Médicales*, October 3, 1885, p. 321.

given the name pyocyanase. It was thought by them to be an enzyme or ferment which was capable of killing and dissolving certain disease-producing bacteria such as the bacilli of anthrax and diphtheria. Much study was given to it both in the laboratory and the clinic for ten or fifteen years, and it was even made on a commercial scale for use in the clinic. It was certainly a powerful antiseptic, but in the course of time the commercial product was found not to contain the active substances, and it disappeared from use in the clinic.

Plant microbiologists have been primarily interested in the never-ceasing struggle for predominance which takes place among the teeming microbial populations of soil, water, decomposing manure and such-like sites. This study, it is obvious, is difficult owing to the complicated physical and chemical conditions which rule in the soil, but emerging from it are some first-class examples of the production of inhibitory substances. It would take us too far to study all the complex antibiotic relations which exist in the soil, in plants attacked by microbial diseases, and so on, nor am I competent to discuss it. I would merely like to call your attention to the fact that in the study of these inter-relations is a vast field not altogether unprobed but still leaving much for further discovery.

You will thus be able to appreciate that for a large number of years data have been accumulating on antagonisms between micro-organisms, due to chemical substances, and it has gradually been realised that these antagonistic substances are produced by a wide variety of organisms. The whole trend in antibiotic work was altered by the impact of modern chemical methods on the investigation of these substances. Methods now known make it practicable in many instances to separate the active antibacterial substance in a pure form from the complex mixture of metabolic products and ingredients of the nutrient medium used for artificial culture in which it is obtained. Such a separation would often have been impossible a few years ago. Chemists are interested from another point of view, too, for many of these substances have proved on examination to be of hitherto unknown chemical structure and are sometimes of profound theoretical interest, quite apart from any question of their practical application in medicine.

It was a botanist who first followed the whole process through from the original observation of an antibiotic action to the extraction in crystalline form of the material responsible. Weindling, in 1932, described the inhibition of *Rhizoctonia solani* by *Trichoderma lignorum* and attributed it to the secretion of a 'lethal principle' which he and Emerson subsequently extracted in 1936 in a crystalline form. This substance they called gliotoxin. It has since been subjected to a comprehensive biological examination, and has been shown to be a powerful inhibitor of certain bacteria as well as fungi, but it is toxic when injected into animals. Nevertheless it is possible that some use may be found for it in the treatment of skin disease due to fungal infections.

In 1939 Dubos described a spore-forming soil organism known as *Bacillus brevis* which produced a powerful antibiotic, now known as tyrothricin. In collaboration with Hotchkiss he showed that tyrothricin consisted of two crystalline polypeptides, gramicidin and tyrocidine. Both these substances have been subjected to a minute biological and chemical examination. Gramicidin (or the crude mixture tyrothricin) has been employed in the clinic for local application to infected wounds and tissues. It is, however, too toxic to be injected intravenously or administered parenterally to animals in any way. It is now on sale for the treatment of superficial infections in man and animals, and it will possibly continue to find some place in medicine, though its usefulness is clearly limited by its toxicity. The two polypeptides are of interest to workers on protein chemistry, who have in them two of the most important crystalline polypeptides. By means of X-ray crystal analysis and chromatography they are being made to yield information of the greatest interest in connection with protein structure.

In 1940 penicillin in an impure form was extracted from a culture liquid on which *Penicillium notatum* had grown, and this extremely powerful antibacterial extract was shown to be of very low toxicity to animals and animal cells. The important point was established that a sufficient amount could be injected into an animal to circulate in the blood stream in an effective antibacterial concentration without doing the animal any harm. It was this discovery which put penicillin into the important and rare class of drug, the systemic chemotherapeutic agent, of which the only previously known group which would act on bacteria was the sulphonamides. It was this discovery which distinguished penicillin from the antibiotics previously investigated, and it was this point which gave rise to the somewhat feverish search which is now going on among the very widespread examples of antibiotic activity for substances endowed with properties like, or supplementary to, those of penicillin.

Methods of Search for Antibiotics

One of the essential points shown by work such as was done on gramicidin and penicillin was that progress could only be expected in

this field when there was a combination of biochemical, bacteriological and other forms of biological research. As a result of the close collaboration between workers with different kinds of technical knowledge, experience has been gained from which it is possible to give a sketch of the steps which must be taken if antibiotics are to be discovered, successfully extracted and purified, and submitted to a complete examination. First it is necessary to find organisms producing antibiotics. These may be sought systematically among the collections of named cultures, such as that of fungi at Baarn in Holland, and the National Type Collection of bacteria and fungi in London. Many of the organisms from these collections have been investigated, and the chemical substances which the active ones produce are gradually being isolated.

Antagonistic organisms may also be sought by the random sampling of soil, sewage, manure or any other material in which bacteria or fungi live in competition. During the war American investigators brought their Services into play, and samples of soil were despatched to the U.S.A. for this purpose from remote Pacific islands and other places where troops happened to be stationed.

One of the simplest methods for detecting the production of antibiotics, which differs scarcely at all from that employed in the last century, consists in streaking a bacterium across an agar plate. The bacterium is allowed to grow for 24 hours, and then various 'test organisms' are cross-streaked at right angles to it. If during its growth the first organism has produced an antibiotic, the growth of the test organisms will be inhibited for a greater or lesser distance from the primary streak.

Fungi such as the *Aspergilli* and the *Penicillia* can be investigated in a similar manner.

A number of methods have been devised for testing whether a liquid culture medium contains antibacterial substances. These depend on observing whether the culture fluid, when allowed to soak into a solid agar culture medium, will inhibit the growth of sensitive bacteria on that medium. Tests of this sort form a good illustration of the dependence of the work of the chemist on that of the biologist, for the biological test has to be used by the chemist for following the unknown active substance through the manœuvres designed to isolate it in a state of purity. Difficulties are sometimes encountered in producing the active substance in liquid medium, because not only do the ingredients of the medium profoundly affect the production of the antibiotic, but factors such as the access of oxygen may be of crucial importance. On some media the fungus or bacterium may grow well and yet none of the substance be produced. Frequently it is necessary to try out many media before a satisfactory one is discovered.

The methods used for testing culture media can also be used for the investigation of other possible sources of antibacterial substances, for example lichens, which are a symbiosis of fungus and alga, and green plants of which my colleague Mrs. Osborn has investigated some thousands. The leaves, stems, flowers, etc., are ground up with sand and extracted, usually with normal saline solution or with some organic solvent. The products can be assayed by the same techniques as are employed for fungal or bacterial products.

Thus the first stage in the investigation of new antibiotics is their production in a liquid medium and their assay.

Chemical Investigation and Isolation

The next stage is the elucidation of some of the elementary chemical properties of the substance contained in the liquid, such as its stability to heat and to changes in hydrogen ion concentration. This knowledge helps to orientate the worker in devising subsequent chemical extraction methods, for it is clear that if the substance is rapidly destroyed by acid, the solutions containing the antibiotic must at no time be allowed to become acid, and so on.

The next procedure is to see whether the active substance can be extracted into organic solvents, for instance, ether, chloroform, benzene, hexane or amyl acetate, and to ascertain whether manipulation of the pH of the fluid will influence the passage between water and organic solvent. There are, for example, many substances which can be extracted from a watery solution into an organic solvent when the medium is made acid, say at pH 2, whereas at pH 7 or pH 8 the substance can be removed from the organic solvent by water, the transfers depending on the different solubilities of the substance and its salts. The extraction of penicillin depends on this sort of manœuvre, and there are quite a number of other antibiotic acids which can be extracted in a similar way.

If the substance is soluble in organic solvents the most profitable methods of purification at present in use are those associated with chromatography. Chromatography consists in passing the mixture of substances it is desired to separate, dissolved in a suitable solvent such as ether, through a column of an adsorbent such as aluminium oxide. During the downward passage of the fluid, the various substances are adsorbed differentially at different levels on the column. Thus 'bands' are formed, which are often visibly different in colour by daylight or ultraviolet light. The column can be further 'developed' by passing

more of the solvent through it. Finally it is separated mechanically into its constituent parts and the adsorbed materials are eluted and tested for antibiotic activity. The activity, if the process has been successful, is confined to one or more bands, and in this way considerable purification and separation can be effected. There are many variations of the chromatographic technique, any of which may be of value.

Those antibiotics which are soluble in organic solvents are relatively easy to purify, but unfortunately many, particularly those produced by bacteria, are not soluble in them, and with these the methods of purification so far devised leave much to be desired. Each substance has to be treated on its own merits, and successful extraction in a highly purified form of these substances often requires a very considerable knowledge of chemical processes in use over a wide field of biochemistry, dealing with many sorts of biologically interesting substances from natural sources. With the extraction of the antibiotic in a crystalline or at least in a highly purified form, a complete survey of its antagonistic and other properties can be undertaken.

Biological Investigation

While chemical isolation is proceeding pharmacological investigations are carried out, at first with impure material if necessary, and then definitively with highly purified or crystalline substance. The toxicity of the substance, both to the intact animals (usually mice) and to individual tissue cells is determined. In addition, examination is made of its effects on the blood pressure and respiration, on smooth muscle, and so on. If this series of investigations discloses that the investigator is in possession of a substance active against pathogenic organisms, with not excessive toxicity either to the intact animal or to the individual cell, that it is not inactivated by blood, nor by other body fluids or enzymes, nor after injection into the blood stream, then it is reasonable to proceed to try whether it will confer any protection on an animal infected artificially with a disease germ known to be sensitive to the antibiotic.

These experiments are usually performed on small animals such as mice, which are deliberately infected intraperitoneally with the organism of the disease under investigation. Such a dose of organisms is chosen that all the animals will certainly die within a short period. It is then possible to show whether the injection of a drug, usually either subcutaneously or into the stomach, has any effect either in prolonging the life of the animal or in securing its survival.

If all the investigations so far mentioned have been favourable, then it is justifiable to attempt to produce the material on a sufficiently large scale for trial in the clinic. I should like to emphasise that clinical investigation comes very late and only after the establishment of all the necessary data in the laboratory.

Some of the Known Antibiotics

The following lists will give you some idea of what recent research has produced :

Antibiotics from Fungi

penicillin	fumigatin
helvolic acid	viridin
citrinin	gladiolic acid
terreic acid	aspergillic acid
claviformin	gliotoxin
chaetomin	javanicin
penicillic acid	glutinosin
mycophenolic acid	ustin
kojic acid	puberulic acid
spinulosin	clitocybine
gentisyl alcohol	polyporin
tardin	hirsutic acid
mycocidin	nudic acid
griseofulvin	sparassol

Antibiotics from Actinomycetes

actinomycin	streptothricin
proactinomycin	streptomycin
grisein	actidione
litmocidin	streptin

Antibiotics from some Bacteria

From species of Bacillus	*From Pseudomonas pyocyanea*
tyrothricin=gramicidin and tyrocidine	pyocyanase = lipoids
gramicidin S	pyocyanine
subtilin	pyo compounds
endosubtilysin	pyolipic acid
bacitracin	*From other Bacteria*
bacillin	streptococcin
licheniformin	nisin
eumycin	the colicines
colistatin	staphylococcin

The Antibiotics from Fungi

You will thus appreciate that already many compounds have been extracted, some in crystalline form, others in a highly purified state. None of the substances extracted from fungi except penicillin has properties which are likely to make it of use in medicine. There is only one other fungal substance—helvolic acid—which has any claim to be considered a systemic chemotherapeutic agent, and its disadvantages are such that it is improbable that it will be used in the clinic.

The Antibiotics from Actinomycetes

From the point of view of the search for substances of medical use, the actinomycetes have proved to be much more interesting. Waksman and his colleagues in the U.S.A. have investigated a large number with a view especially to finding antibiotics which only act against the tubercle bacillus and other organisms which are not affected by penicillin. Many antibiotics are known which are quite active in preventing the growth of the tubercle bacillus *in vitro* but few of them look like having any therapeutic application on account of their toxicity or other undesirable properties. Clearly a substance to be used in treating a chronic disease with complicated pathological lesions will require to be of very low toxicity, for it must be given, possibly without intermission, over a long period of time. Waksman and his collaborators isolated from an actinomycete known as *Streptomyces griseus* a very active substance which they called streptomycin. It has a relatively low toxicity to animals and man and has many other good features. It suffers, however, from one serious drawback, which is that most bacteria, including the tubercle bacillus, rapidly become immune to its effects. Recently, for example, observations have been made which show that the tubercle bacilli infecting a patient may at the end of a few weeks' treatment need 10,000 times the concentration of streptomycin to inhibit growth which they needed at the beginning.

Precisely how much can be expected from streptomycin in the treatment of tuberculosis has yet to be determined, but it is already clear that too much hope should not be centred on it. Nevertheless, it is a true systemic chemotherapeutic agent which produces spectacular effects in an acute disease unknown in this country—tularæmia—as well as in some other conditions. Streptomycin is likely to hold a place in medicine for many years, and in the U.S.A. many millions of dollars have been spent on its large-scale production.

Industrial Production

One of the most interesting developments of the last five or six years has been the raising of the level of production of antibiotics from that which can be accomplished in the laboratory to that of gigantic engineering works. You are probably familiar with pictures of the large-scale penicillin plants, but you may be less so with the fact that in America large plants exist for the production of streptomycin, and facilities for the production of other substances on a large scale as soon as it appears worth while.

As this lecture is given under the auspices of an association for the Advancement of Science, it may perhaps not be completely inappropriate if I point out that nearly all the chemical engineering developments associated with these biological processes are due to the U.S.A. This is no accident, but is in my opinion due to our lack of people suitably trained for such work. It is also no accident that, although penicillin was a British discovery and was introduced into medicine in this country, most of the significant work on it now comes from the U.S.A., for their great production facilities enable them to supply their research workers liberally with the crystalline penicillins, of which there are several kinds with different chemical structures.

The Antibiotics from Bacteria

Much interest is being displayed in the antibiotic products of bacteria, especially those produced by the great group of spore-bearing organisms found in the soil. I have already mentioned the extraction from *Bacillus brevis* of tyrothricin by Dubos in 1939. Since that time, substances which have been given the following names have been extracted from various types of soil spore-bearing organisms: subtilin, bacitracin, bacillin, colistatin, endosubtilysin, licheniformin—and there are others which have not been given specific names. Though probably most of these substances are similar in chemical nature, the evidence at present available is that they are different one from another. One of them, bacitracin, has been investigated in considerable detail. It has been shown in the laboratory to be a true systemic chemotherapeutic agent, acting against a range of organisms similar to that acted upon by penicillin. It has been used in the clinic in America on a considerable scale. It is possible that we may hear more of this substance, which is still in the relatively early stages of investigation.

Licheniformin, which has been investigated by Callow and Hart in this country, has been shown to possess systemic chemotherapeutic action against experimental infections in mice. As far as I know, no clinical trials have yet been done on man.

Subtilin also possesses properties which may make it of use in the treatment of disease in man, but so far only local application to infections in animals has been reported.

About bacillin and endosubtilysin there is not yet enough published evidence to enable one to form a judgment of their potentialities.

Colistatin, which was extracted in Russia, is remarkable in that it acts against organisms unaffected by the other substances just mentioned.

There are innumerable different strains among the many species of these spore-forming organisms, and already there is evidence of the production of other substances besides those which have been extracted and named. This group of bacteria remains a potential source of new substances useful in therapeutics as well as of intrinsic interest.

Antibiotics have been extracted from other kinds of bacteria, such as the streptococci. One comes from a kind of streptococcus which was first encountered during the making of cheese, by reason of the fact that its antibiotic action interfered with the normal effects of the micro-organisms used in cheese-making. From the streptococcus Oxford extracted a substance which he named diplococcin, a protein which, from his description, appears to have little prospect of being of value in therapeutics. Mattick and Hirsch reported the extraction of a substance called nisin from another streptococcus, and this has chemotherapeutic properties in animals.

Another extremely common organism—we all carry it in our intestinal canals—is *Bacterium coli*. Many strains of *Bact. coli* produce antibiotics. There is evidence that these differ one from another but that they are similar in chemical nature. One of these has been investigated in detail by Heatley and myself, and it was found to produce a substance which is extremely specific in its effects. It is effective against some strains of *Bact. coli*, but not against all ; it is effective against one strain of an organism which causes dysentery, slightly effective against two other strains, and completely ineffective against all other organisms so far investigated. It is extremely powerful, for under certain conditions it will inhibit the growth of a sensitive organism at a dilution of 1 in 60,000,000, but it is destroyed by trypsin and pepsin and by body tissues, so that it has no prospect as a chemotherapeutic agent. However, its extraordinary specificity is a property which makes it worthy of further investigation, from the point of view of throwing light on the actual manner in which these substances interact with the bacteria whose growth they inhibit.

Plant Antagonists

Besides the micro-organisms—bacteria, actinomycetes and fungi—which we have been considering, the possibility exists that plants may furnish antibacterial substances useful in medicine. In spite of the fact, however, that plants have been studied since antiquity as a source of drugs useful for healing wounds, the systematic searches which have recently been made for antibacterial substances have so far failed to disclose any of interest to medicine.

The Problem of Mode of Action

From the very large volume of work which has been conducted in nearly every country in the world, we know that micro-organisms produce a considerable variety of different types of compounds ; some are proteins, some are polypeptides, some amino acids, some contain sulphur, some contain nitrogen, some are quinones, some phenols, and some are substances of unique chemical structure previously unknown to the organic chemists.

One of the big biochemical problems still unsolved is how these substances act on the susceptible bacteria. As yet we do not know even how penicillin works, though it has been much studied, but we do know that antibiotics do not all produce their effect in the same way. Further analysis of the chemistry of such substances and of their mode of action may perhaps enable us eventually to synthesise chemotherapeutic agents suited to inhibit the growth of particular bacteria.

I hope I have been able to indicate to you the long history of the study of antibiosis and the direction in which it proceeds at present, and to give you some idea of how this research is being carried out.

THE SENSE OF SMELL

By Professor E. D. Adrian, O.M., F.R.S.

In the Alexander Pedler Lecture, which he was appointed to deliver by the Council of the British Association, Professor Adrian gave his first account of some new work which he has undertaken on the sense of smell. The lecture, which was illustrated by lantern slides and gramophone records, was delivered to a public audience in the Royal Institution, Albemarle Street, W. 1, on May 14, 1947.

We know so little about the sense of smell that I must start by excusing myself for choosing such an unusual subject for a lecture. My only excuse is that it is unusual. I am sorry to say that I have not much to add to the little that is known ; but the physiology of the olfactory organs has been too much neglected, and it illustrates some important principles in the physiology of sense organs in general and in the physiology of the brain, of how the sense organs are used.

To begin with there is the fact that the organ of smell is a large and important sense organ, often the most important guide to the behaviour of the animal, more important than the eye and ear. Yet although we have a fairly clear idea of how the eye and the ear convey their information to the brain, we have no clear ideas about the nose. No doubt this is partly because physical events are less complex than chemical. We can make instruments which will do all the eye and ear can do, instruments such as the television camera and the microphone, but it would take an army of chemists to plan anything like an artificial nose, if it was to signal more than a very limited number of smells. But there is another reason for our ignorance about smell which comes from the way in which the human brain has developed, from the way in which we use the information which comes into the brain from the sense organs. Their signals help to decide what is the appropriate line of behaviour from moment to moment, but as the brain has extraordinary powers of storage and classification our behaviour at this moment is not merely determined by the sense impression of the moment, but by sense impressions which happened a year ago or twenty years ago, by what we learnt when we were babies or at school as much as by what we are seeing and hearing and feeling now. We abstract, classify and file away our sense impressions and we act on them and make our decisions to the accompaniment of the process which we call thought : and our thought makes use of visual and auditory and kinæsthetic impressions but not of olfactory.

One reason for this may well be that smells are rather leisurely sensations. Owing to the nature of the stimulus and the sense organ they cannot change as rapidly as sights or touches. They could not be used for sending complicated messages between one animal and another as we use sound, but only to indicate one thing at a time. And a more important reason is that they cannot be built up into the system of three-dimensional space which we use as a framework for our ideas. The baby moves its hands, feels the movement and sees the corresponding change in its visual field and so it can work out the scheme for relating these two kinds of sensory impressions, visual and kinæsthetic. And later we are taught to speak and to recognise the sounds which we use as labels for particular sights, and when we have learnt this we can talk to other human beings and make our system of ideas match theirs. And the system is so convenient that all our thinking comes to be done in terms of sight and sound labels—words ; it is from these that we build up our system of communication and thinking. We can recognise a great many different smells but we have never come to use them as symbols in argument.

For us, therefore, smells cannot be analysed and discussed in the same detailed way that we can analyse and discuss the visual field. But clearly animals which have never developed our system of classifying visual and auditory and tactile impressions may be far less tied to sight and hearing, and clearly many of them get far more information out of smell than we do. It may not be much more than the immediate recognition of different smells which we ourselves have in some measure ; but it can be none the less a far more important factor in their decisions because all are probably made at this level of complexity, without the intervention of our kind of thought.

The importance of smell to most animals is attested by the very large size of the olfactory organs. This statement needs some elaboration, however, for it raises a fundamental point about the working of the sense organs in general, and we ought to deal with

this before we consider the nose in particular. The point is merely that the nervous system, and that includes the receiving elements of the sense organs, is built up out of a very large number of units which are all much alike. They are the nerve cells with long conducting threads called nerve fibres. These are living cells and have all the mysterious properties of living cells—powers of growth, adaptation and so on—but their specialised activity as units of the nervous system is not as complex as one might suppose. The long conducting threads, in particular, can only conduct one sort of activity, the nerve impulse, a brief surface change which can spread very rapidly. The nerve fibre, in fact, is a much less versatile signalling arrangement than a wire carrying an electric current, for all it can do is to transmit a succession of similar impulses.

It follows that the signals which come into the brain are all very much alike, whether we are dealing with a nerve fibre from the eye giving a sensation of light or one from the ear giving a sensation of sound. The signals have to be all in the same form because there is only the one kind of nervous transmission.

This can be illustrated by the electrical records which can be made of the signals which go up the nerve fibres from various sense organs. They show the potential changes which sweep along the nerve fibres, and there are various methods by which we can record what is happening in each conducting unit. What happens is a series of brief potential changes succeeding one another at intervals which may be as short as $\frac{1}{200}$ second or as long as $\frac{1}{5}$ second. The frequency varies with the intensity of the stimulus, but the signal in one of the fibres of the auditory nerve is no different from that in one of the fibres of the optic nerve : the message from the ear is in the same terms as that from the eye.

You will see our disregard of smells more clearly if you consider how I am trying to communicate these points about the messages in nerve fibres. The potential waves, or nerve impulses, can be shown on a photographic plate, a picture in which time is represented by horizontal distance, a convention we have all learnt. They can be illustrated better in some ways as sound by reproducing each electrical disturbance as a sharp click in a gramophone record : this gives a more direct idea of the time relations in a sequence of impulses. It would not be possible to bring out the salient points by presenting the record as a succession of smells, because smells rise and decline too slowly to show how the impulses succeed one another ; but even if I were trying to describe a much slower sequence of changes it would be absurd to do it by letting off a succession of whiffs of smell. You would see no sense in it and would immediately translate the experience back into visual and auditory imagery.

Now to return to the nature of the signals, the process of transmission is much the same in all the nerve fibres that have been examined. There are differences in the rate of travel and in the duration of each impulse according to the size of the fibre, but the nature of the impulse seems to be the same in all. A single fibre, therefore, can signal that something has occurred to start a train of impulses, but there will be nothing specific about the impulses to tell us what sort of change it was that started them. We can tell how the stimulus rises and falls in intensity, because the impulses will be more closely crowded when the stimulus is intense, and we can tell when it begins and ends and how it fluctuates. But that is all that the individual nerve fibre can show us.

Yet although the information sent along each nerve fibre is strictly limited, this does not mean that our sensory impressions must be so too. The very simple records from the individual conducting units do not give a fair idea of what goes into the brain, for that is made up of a large number of these trains of impulses sent in independently by many fibres. But the simplicity of the message in each fibre does mean that the more complicated the information the sense organ has to provide, the greater the number of nerve fibres which must be employed to carry it.

To project something corresponding to the visual scene on to the receiving area of the brain, the eye needs a million nerve fibres, each leading from one group of light sensitive elements in the retina. The ear has only to signal all the components of a sound, but even so it needs about 80,000 nerve fibres to do it, and when we come to the nose we find that the number of fibres may be even greater than those from the eye with 10 or even 100 million receptors to form the signal.

Such a large number cannot have very much to do with sensitivity. The nose is, of course, an extremely sensitive detector, but the sensitivity will depend on the excitability of the individual units—not on their number. It follows that the very large number of receiving units and transmitting pathways in the nose must mean that there are very complicated patterns of excitation to transmit, patterns as complex as those which give us our picture of the visual field.

The resemblance between the eye and the olfactory organ is not only a matter of the large number of elements in them but of their nervous organisation as well. In both of them there is the same kind of complex network of nerve cells and branching fibres

immediately behind the receiving units, for the signalling system would be too unwieldy if each of the 100 million units had its own nerve fibre to the brain, and so the messages are condensed and edited in these converging pathways before they are sent on. This editing involves a great deal of intercommunication between the different pathways. It takes place in the nervous layers of the retina and in the structure known as the ' olfactory bulb ' which lies close to the sensitive area in the nose.

To begin with, however, the olfactory message, like the visual and auditory messages, must start from the receptors, the olfactory cells which are the equivalent of the rods and cones in the retina and the hair cells in the ear. The olfactory receptors are long slender cells with hair-like processes which project into the slimy layer which covers the surface. We know that they contain a good deal of fatty, lipoid material, but that is about all we do know. The cells are not as closely packed as those in the retina, for there are a good many columnar cells between them, and they are set in a surface which is thrown into folds and played on by a current of the medium in which the animal lives—air in air-breathing animals and water in fish. They are obviously extremely sensitive to chemical stimuli. It has been calculated that 200 molecules of mercaptan per cell are enough to excite, to alter the surface enough to make it start discharging impulses. But if only five quanta or less can stimulate a rod of the retina, these quantities are not so surprisingly small, and there are instances of cells reacting to just a few molecules instead of as many as 200.

It is worth considering the structure of the olfactory organ in fish, for in mammals the nose has other functions as well, whereas, in fish the organ can be seen for what it is, a structure comparable to the eye. It takes the form of a pit on either side of the snout, roofed with skin with openings in front and behind. The water in the sac is constantly changed by ciliary action and by the gill and swimming movements. The sacs contain a large number of vertical plates covered by a mixture of epithelial cells and of the true olfactory cells, which send fibres back to the olfactory bulb where the messages are condensed. The total surface of the plates is large (in dogfish and sharks, for instance, the total surface is as much as 30 cm.^{2}), but only the tops are directly exposed to the water current ; this is an important point, for it seems to be the characteristic arrangement of the olfactory receptors.

The arrangement in the mammal is not very different. The receptor surface is again thrown into narrow folds and it is tucked away at the back of the nose so that the main air current will just reach it. There are other folded surfaces in the nose which help to warm and moisten the air before it reaches the lungs, and these direct the current down to the opening of the windpipe and keep it from playing directly on to the olfactory region unless a deep or rapid inspiration, a sniff, is made. In man the olfactory area measures about 5 cm.^{2} and lines a narrow cleft at the top of the nose just under the brain.

Now even man, who relies so much more on sight and hearing, can recognise a vast number of different smells and can train himself to distinguish more, and animals which rely more on smell can obviously make out all sorts of fine distinctions to which we are insensitive. The chief problem, then, is to find out how the messages vary so that we can distinguish one smell from another, how the signals sent to the brain by the smell of an onion differ from those sent in by the smell of coffee.

It is highly improbable that there are specific receptors sensitive to all the different smells we can recognise ; to a bloodhound, for instance, each new criminal has his own distinctive smell and there cannot be special nerve endings, one for each of the criminal population. So it is natural to think of smells as compounded out of the excitation of a limited number of different types of ending, and there have been many attempts to liken our power of distinguishing smell to our power of distinguishing colour, to find three or four primary smells out of which the whole series can be made up.

It cannot be said that any such primary odours have been isolated, though smells can obviously be classified into various groups—fruity, aromatic, foul, and so on : many smells can be reproduced by suitable combinations, but not the whole range. And naturally there have been various attempts to find the physical and chemical characteristics which give rise to smell, again without much success. Substances which are quite inert chemically are smell-less, and substances soluble in oil are more likely to smell than those only soluble in water ; but that merely means that to stimulate the olfactory hairs the material must be capable of getting into them and causing some chemical change.

It seems, therefore, that our inability to think about smells, to compare them and sort them out, may make it extremely difficult to get much further on these lines, where all we can do is to relate the substance which stimulates to the simple unanalysable sensation it produces. But we can try another method ; we can try to record the nervous messages which pass from the nose to the

brain. There must be something in the message which is characteristic of the smell and we should be able to discover how the message varies when the smell is changed. The method has been used with success for the eye and the ear and there are only technical difficulties in the way of using it for the nose as well. I shall describe some of the results of this method ; they are only preliminary results and have not yet solved the problem, but they show that the olfactory messages are really no different from those of other sense organs and they show some of the many possible ways in which the message of one smell may differ from that of another.

The method is simple enough. The olfactory messages can be recorded by opening the skull to expose the bulb and thrusting a fine wire (insulated except at the end) down through the bulb until the top is in contact with the nerve fibres which run in the tract to the brain. It must be done on a deeply anæsthetised animal, and the results depend to some extent on the depth of anæsthesia : anæsthetics depress the activity of nerve cells and of the cells in the olfactory organ to some extent ; but this is to some extent an advantage, for it means that in deep anæsthesia we shall have fewer units in action, only the more resistant and more active, so that it will be correspondingly easier to see what they are doing.

The records which we can obtain in this way from the rabbit's olfactory bulb will show the electrical activity in more than one fibre, and when a large number are in action together it may be very difficult to make out what is happening. But it is usually possible to adjust the electrode so that the individual nerve impulses can be seen, and when this has been done we can record what happens when various substances which have a distinct smell are placed under the nose. As a rule there will be a short discharge of impulses at each breath, and the discharge will become much greater when the smell is present.

The discharge which occurs at each breath, before the smell is added, needs some explanation. It is a fact that however deep the anæsthesia a discharge of impulses can always be produced by blowing or sucking air through the nose, however pure the air may be. This is an important point : we can never be sure that the air will have nothing in it to stimulate chemically, but the discharge seems to depend very much more on the mechanical effect of the air current than on the chemical substances which it may bring to the olfactory cells. Since the production of a discharge of impulses is probably due to a disturbance of the surface membrane of the olfactory hairs, it is not at all unlikely that activity might be set up either by movement alone or by chemical action alone, and that movement and chemical action might reinforce one another when they occur together. At all events, when the air is fairly pure its movement through the nose seems to be the chief factor in making the olfactory cells discharge, and when the air has a distinct smell the same cells will discharge at a higher rate and more cells will come into action.

Photographic records can be made of these olfactory discharges, but it is often possible to extract more information from the record when it is presented to the ear rather than the eye. It is true that a visual record can be analysed at leisure, but a sound record will give a much clearer idea of the time course of a series of events, if they are not too fast or too slow, and we can often pick out time sequences more easily by ear. In this sort of experiment, therefore, it is always as well to have a continual sound record made by turning the electrical oscillations of the nerve fibres into a loud speaker, and the typical effect of various smells can be illustrated better from gramophone records than from photographic. Through the kindness of Mr. Kirke of the B.B.C., I have been able to borrow the necessary recording gear and to make a series of records which illustrate the main features of the olfactory discharge.

The simplest effect, an increased discharge at each breath when the smell is there, does not tell us very much. It shows that the receptors are stimulated by the substance in question, but that is all, and the nose will not be as sensitive as it would be if there were no anæsthetic to reduce the excitability of the nerve cells. The results, indeed, are no more than one might expect. The rabbit's nose reacts well to fruity and aromatic smells—to the smell of fresh grass, dried herbs, clove oil, etc., though it seems rather insensitive to foul smells, like that from decaying animal matter. The cat's nose, on the other hand, has not reacted so far to herbs or flowers, but reacts strongly to foul smells and animal matter. One rather sensitive preparation reacted strongly whenever I came close to it.

But with slightly less deep anæsthesia and slightly stronger smells the result is rather more informative. The smell will not only stimulate at each breath but the discharge will continue in the intervals between and in some of the discharging units the breathing rhythm will not make much difference. Thus in a gramophone record of the discharge produced by clove oil, it is possible to detect one unit coming in after a time and continuing in action with very little pause as

long as the smell is there. In this case the units which give the discharge seem to be more affected by the chemical stimulus and less by the combined effect of movement and chemical stimulation.

Now if one considers the typical arrangement of the olfactory surface, it is clear that some of the cells, those which are nearer the main cavity of the nose, will be much more accessible to the air current, whilst others must be reached mainly by diffusion. The latter might be expected to start their discharge more gradually, and when it does start the discharge will show less fluctuation with each breath. In man these cells will be at the top of the olfactory cleft and in the rabbit they will be the cells which are furthest from the exposed part of the olfactory folds. We might expect to reach these cells more easily by using substances of relatively low molecular weight, substances which will diffuse quickly, and the evidence suggests very strongly that we can do so. There are a number of organic solvents like xylol, petrol and ether which produce a very large olfactory discharge when they are brought near the nose. A very slight intake of air is all that is needed to start it, and the discharge is often quite continuous with no fluctuation related to the breathing, though the usual discharge at each breath can often be heard in the background and becomes more obvious as the noise subsides.

The diffusible vapours which produce such a continuous effect are often without an intense smell, but the magnitude of the discharge shows that they have access to a very large number of olfactory receptors. Their effect would be comparable, therefore, to that of a general illumination of the visual field rather than to an intense illumination of one part of it and this may explain why they do not produce a very strong smell. But clearly the nature of the discharge which they produce shows one way in which different substances may be able to produce different patterns of excitation in the olfactory surface. Substances which do not diffuse so well will affect only the more exposed olfactory cells and substances which diffuse readily will go further up the cleft and reach a larger area.

It seems then that the particular structure of the olfactory apparatus, the folded membrane with some parts much more accessible to the air current than others, will make it capable of differentiating smells to some extent according to the rate at which the molecules can diffuse. And the fact that there is the same kind of arrangement in fish, though on a smaller scale, increases the likelihood that this kind of analysis may be important.

It is true that an analysis in terms of molecular weight, or diffusibility, alone would not take us very far in sorting out different substances by smell. But an analysis in terms both of molecular weight and of the stimulating effect of the molecules on the olfactory cells would give much more differentiation. It would be unlikely to account for the whole gamut of different smells, and no doubt there are some receptors which are specially sensitive to certain substances or certain molecular conformations. But it is quite clear from records of the olfactory discharge that there are many receptors which can be excited by a wide variety of different smells. Sometimes a fresh nerve fibre will be brought into play by a fresh smell, but evidently a large number of the receptors are not particular and react to almost any chemically active substance which reaches them. This lack of specificity in many of the receptors is not as surprising as it may sound, for we meet with the same thing in the eye. Granit has shown recently that most of the rods and cones react to light of all colours and that there are only a few which are specially sensitive to particular wavelengths. These give the colour and the majority give merely the light and shade. In the same way there may well be some olfactory cells with special chemical affinities, although the majority may have very little.

It will obviously be necessary to search for the more specific kinds of receptor in the nose, but a great deal of differentiation may be possible without them. In the records which can be made, the discharge in each unit will often show a characteristic form which varies according to the smell. One unit may come in suddenly at a high rate of discharge, whilst another smell will make it discharge at a lower frequency but for a longer time. Differences of this sort probably depend on physical as well as on chemical properties, but they seem to be characteristic for the particular group of receptors which supply the fibre whose discharge we are recording.

When a particular smell reaches the olfactory organ, therefore, the receptors will come in at different rates and different times, according, no doubt, to their chemical affinities, but also to their position on the olfactory surface. One after another will come in like the different instruments in an orchestra, and just as the ear can recognise all the fine shades of a chord built up progressively, so the nose may be able to distinguish the nature of the smell from the evolution of the discharge in the different nerve fibres. Such an evolution can often be followed in the sound records which we can make of the olfactory discharge.

It must be emphasised that we are still severely limited by technical difficulties, and that much more work will need to be done before we are likely to be on firm ground. But the method gives a reasonable indication of the sort of messages which give rise to the sensation of smell and shows why the sensation has its particular character. The pattern of excitation transmitted to the brain will be not unlike the pattern of excitation which comes from the retina or from the ear, for the focus of activity will shift from one part of the olfactory membrane to another in much the same way as it may shift in the retina or the basilar membrane of the cochlea. We can recognise the visual pattern whether it is small or large, brightly or dimly lit : the exact part of the retina which is stimulated does not matter very much so long as there are particular relations in the pattern. We can recognise a voice whether it sounds softly or loudly. In the same way, therefore, a faint or a strong smell may preserve its character, because the pattern of excitation on the olfactory membrane will keep certain distinctive features although the area and intensity may alter.

We have learnt to recognise innumerable visual and sound patterns, and we often recognise them without analysis. There must be many faces and voices which we would recognise like this, though we might be able to analyse them if we needed to do so. We can recognise smells in the same way, though in this case we cannot analyse them at all ; and just as there are innumerable possibilities of varying the visual pattern, so there may be olfactory patterns of all kinds and of all degrees of complexity.

Animals which rely more on smell presumably have a much better apparatus in their brains for dealing with the olfactory patterns they receive, so that the dog can probably recognise distinctions to which we should be quite inattentive, just as we should recognise distinctions between one page of print and another, a distinction to which the dog would be blind. Thus the dog may find many significant features to distinguish the olfactory pattern of one man from another and we may not be aware that the patterns exist. ' Pattern ' is perhaps the wrong word, for it implies something like the visual pattern, the printed page, or the auditory—a chord or a tune or a voice. Yet the olfactory signals must consist of impulse messages like those which produce sight and hearing. The olfactory pattern will not be quite like anything else, but it is easier for us to try to think of it as though smells were built up in the same way as sounds or sights. Our difficulties may be partly due to this, for clearly the olfactory pattern has its own special features. We are not likely to understand it unless we are constantly reminding ourselves that though the impulse messages are much the same we have not learnt to use them in the same way for making our mental pictures of the external world.

PETROLEUM TO-DAY AND TO-MORROW

By Dr. Kirtley F. Mather

In 1938 the British and American Associations for the Advancement of Science established an exchange lecture to be delivered at meetings of each Association in alternate years. The first lecture to the British Association was due to be given in 1939 by Dr. Isaiah Bowman, but the outbreak of war prevented Dr. Bowman from delivering it although he had crossed the Atlantic to do so. His text was printed in The Advancement of Science (Vol. I, No. 4, p. 552). The war prevented the two Associations from maintaining the lecture as planned, and it was not until 1947 that the British Association was able to invite an American scientist to inaugurate the series in person. Dr. Kirtley F. Mather, Professor of Geology in Harvard University, was invited to lecture to the British Association at its meeting in Dundee, where, on August 29, he addressed an audience which filled to capacity the largest hall available. The lecture, of which the following is the text, was illustrated with lantern slides.

From almost every point of view, petroleum was ' strategic mineral number one ' during the World War that ended in 1945. Even the spectacular advent of the atomic bomb in the final days of the conflict did not displace it from its position of prime importance, although within a few years uranium will almost certainly be the ' number one ' material in the minds of military strategists, if indeed it is not even now in that position.

It was the ceaseless flow of petroleum from the oil fields of the United States, Venezuela, the Middle East and a few other places of lesser importance, that kept the Allied forces

in motion on land and sea and in the air, the world around, and even provided them with some of the most potent of their weapons. It was the progressive attrition of Germany's supplies of oil that clipped the wings of the Luftwaffe and made possible the astonishingly swift advance of the Allied forces from the periphery of Hitler's ill-gotten empire to its nerve centre in Berlin. It was the cutting of the supply lines from the oil fields of the East Indies to Japan, and the exhaustion or destruction of the Japanese stores of petroleum, that presaged the capitulation of the Japanese war lords, even before the bombs fell on Hiroshima and Nagasaki. Verily the Allied Powers rode to victory on a flood of oil.

Now that the 'shooting war' is ended, petroleum continues to hold its leadership among the natural resources of the earth, as we turn to the distressingly difficult task of arranging a peaceful world in which men may use for the welfare of all mankind the rich resources of our bountiful earth. Both as fuel and as raw material for chemical industries, petroleum will hold the centre of the stage for many years to come. Hardly any other substance illustrates so fully the manner in which science and technology may be combined to achieve the utmost success in contributing to human efficiency and comfort.

Fundamental to any understanding of the problems implied by my topic is the comprehension of the fact that petroleum is a non-renewable resource; it is in the category of nature's stored capital, not of man's annual income. It is of course true that the same geologic processes responsible for oil pools are continuing to operate to-day as in the past. On the sea-floor off the coast of southern California, for example, there are broad hollows where the tissues of marine animals and plants are now accumulating in mud and ooze at depths of two or three hundred fathoms. The conditions are closely similar to those that recurred repeatedly during the Palæozoic era in Oklahoma and Texas, when the oil of certain rich oil fields was being generated. But millions of years must elapse before that organic material can be transformed into petroleum, stored in the interstices of overlying sandstones, and made available by crustal movements for recovery from wells to be drilled by some future inhabitants of the earth's surface.

In relation to the feverish haste of mankind's insatiable demands, the creative processes of nature's laboratory operate very slowly. For all practical purposes our planet must be reckoned as a storehouse of such minerals as petroleum, not as a factory in which that substance is generated year by year, or even millennium by millennium. Mother Earth has made available a cupboard richly stocked with a vast amount and a great variety of goods indispensable to us in an age of science and technology, and among these stores we find petroleum. Each year we go to the shelves of that cupboard and take away a few packages of the goods stored thereon; if we keep going long enough, some day somebody will find that the cupboard is bare. Indeed, petroleum is now being used at such a rate in relation to its total amount in the earth's crust that its complete exhaustion is, from a geological viewpoint, alarmingly imminent.

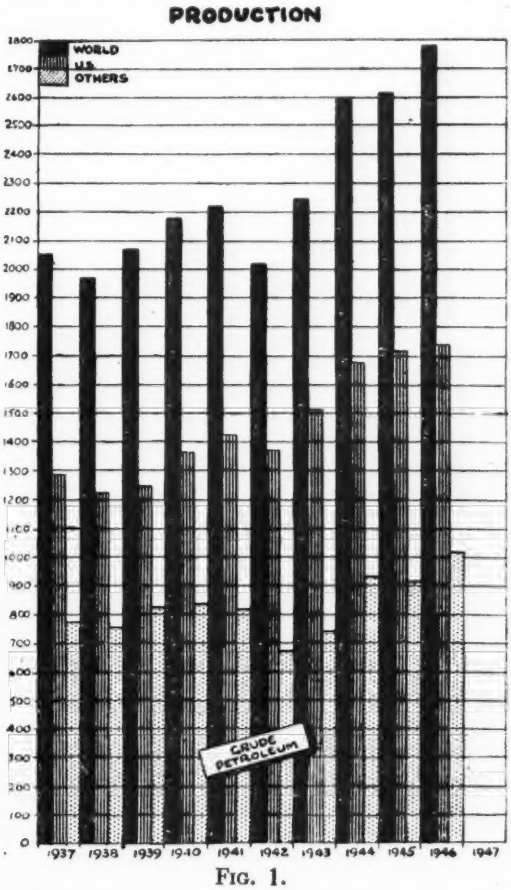


FIG. 1.

Between 1859, when the first oil well was drilled in the United States, and January 1, 1947, the production of petroleum from all parts of the world has totalled nearly fifty-two thousand million barrels. Of that total, slightly more than thirty thousand million barrels (30,150,000,000 bls.) was produced in the United States. As shown in Fig. 1, the annual production, both for the world as a whole and for the United States, has increased each year since 1938, with the sole exception of 1942, the first year of American participation in the war, and there is every indication that these increases will continue for the next few years. Indeed, it is probably a conservative estimate that the world's oil pro-

duction will average more than three thousand million barrels per year during the decade 1947–56.

Such figures begin to take on real significance when we note that the most recent estimates made by competent petroleum geologists (see Fig. 2) give a figure of slightly less than seventy thousand million barrels (68,924,000,000 bls.) for the proved reserves of petroleum throughout the world on January 1, 1947. It would, however, be far too simple and quite erroneous to make the easy arithmetical calculation and announce that the world's oil will be exhausted in twenty-three years. The proved reserves are only a fraction of the actual reserves. Whether the fraction is one-half or one-tenth is a matter of great moment, requiring careful consideration.

The particular combination of specifically defined geological conditions requisite for an oil accumulation of economic value is now well known to petroleum geologists. Every

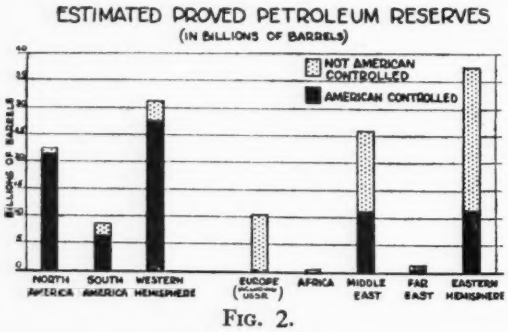


FIG. 2.
Billion = 1,000 million.

oil field fulfils the specifications in one way or another, and the failure to find oil in an exploratory borehole can almost always be explained by an observable lack of one or more of the requisite geological conditions.

The first requirement is an adequate source of supply of the organic materials from which petroleum may be formed by natural processes of a biochemical and geochemical character. Source beds are sedimentary rocks, most commonly shale, but in some instances limestone or sandstone, in which the tissues of plants or animals were buried, before they were completely oxidised, while the sediments were accumulating on a sea-floor, lake-bottom or stream-bed. Certainly almost all, and very probably all, adequate source beds are of marine origin.

In the second place, there must be a suitable reservoir rock in fairly close proximity to the source beds. Reservoir rocks must be both porous and permeable, in order to provide space for the oil in the interstitial voids and to permit its movement, first from the source beds into its interstices and later from them into a borehole. The best reservoir rocks are sandstones and limestones with a porosity of 5 to 25 per cent. of their volume and with permeability ranging from one or two hundred to one or two thousand millidarcies. It is not essential that a reservoir rock be marine in origin; lacustrine, fluviatile or eolian sandstones will do just as well. In fact, a volcanic ash deposit, a tuff or agglomerate, might be quite satisfactory.

Thirdly, there must be some sort of trap to prevent the upward migration of the oil as it seeks to ascend to the surface because of its lesser density than that of water. The trap may be (i) 'structural,' produced by folding or faulting of the rocks, or a combination of the two, or by the intrusion of salt or igneous rock into the sedimentary series, or (ii) 'stratigraphic,' resulting from the pinching out of the reservoir rock up dip, or from excessive lateral reduction in porosity or permeability within the reservoir bed, or formed by the unconformable deposition of relatively impermeable beds across the eroded edges of tilted strata that include a reservoir rock.

Finally, the sedimentary system containing source beds and reservoir rocks must not have been unduly metamorphosed, either as a result of deep burial, horizontal compression during mountain-making movements, or igneous intrusions on a large scale. Moderate pressure stimulates geochemical changes conducive to the evolution of petroleum from its source materials, but excessive pressure destroys petroleum. Gentle folds are desirable to provide structural traps and to tilt reservoir rocks so that the oil can move upward into stratigraphic traps, but closely compressed folds do not yield oil. The greatest depth from which oil has thus far been produced is slightly greater than 13,000 feet, although several holes have been drilled deeper than 15,000 feet and at least one exceeds 17,000 feet. It is extremely unlikely that oil will ever be produced anywhere from depths greater than 20,000 feet. At such depths, pressures and temperatures are too great to permit petroleum to exist in the fluid state.

Although geological and geophysical surveys at the earth's surface permit the discovery of places beneath which one or more of these four requisites for an oil field are known to be met, no one can guarantee in advance of drilling that oil will be encountered at depth. Satisfactory criteria for the identification of source beds as such are not yet known. Sedimentary rocks are notorious for their facility to change in textural, lithologic and mineralogic characteristics when traced laterally from place to place. There was no reason, for example, to expect in advance of drilling that the structural trap

a few miles south of Lincoln in Nottinghamshire would be devoid of oil, whereas the very similar structure in similar rocks at Eakring, only 25 miles distant, would yield very considerable production. Not until the drill has yielded information concerning the texture and thickness of potential reservoir rocks within the favourable structure itself and has demonstrated the actual presence of petroleum can one begin to calculate the quantity of proved reserves for any oil field.

The relation between proved reserves and the total supply of petroleum in the ground is best indicated by the history of American oil fields. Almost every minor variant of the geological conditions essential for an oil pool is found somewhere within the extensive petroliferous area of the United States. Accurate records of nearly all drilling operations and of the resulting production of oil and gas are available over a long period of years. American geologists have specialised in the computation of known and probable reserves for each of the many oil fields at various stages in their development, from the drilling of the ' discovery well ' to the exhaustion and abandonment of the older fields.

The broad picture is indicated in Fig. 3. During the eleven years from 1936 to 1946 inclusive, there has been an intensive search for new oil fields, the results of which have made possible the increase in annual production from approximately one thousand million barrels in 1936 to nearly seventeen hundred and forty million barrels in 1946. In spite of the removal of this vast quantity of oil, the proved reserves have been greater at the end of each year than at the beginning, with the sole exception of 1943 when there was a relatively small amount of exploratory drilling, because of the limitations upon steel for well-casings imposed by the necessity of allotting large quantities of steel to shipbuilding and military equipment. It will be noted, however, that the curve entitled ' Proved Reserves at End of Year ' rises steeply for only four years, from 1936 through 1939, and thereafter shows a definite tendency to level off. There is little doubt that the peak of that curve will be recorded by 1950 and that thereafter it will descend toward zero.

This somewhat gloomy forecast is borne out by a more detailed study of drilling operations in the seventeen states that include the major part of America's petroleum resources. The number of exploratory holes drilled in that area increased from 2,700 in 1938 to 5,400 in 1946, but the number of wells that discovered new fields fluctuated within very narrow limits and was only a little larger at the end of the selected period than at its beginning. Especially disappointing is the fact that there were fewer successful exploratory wells in 1946 than in 1945, although the total exploratory holes drilled in that year was appreciably greater than the year before. In spite of the increased expenditure for exploratory drilling, the number of new fields discovered has decreased each year since 1943. Especially significant is the fact that the number of major fields (confidently estimated to contain over 10 million barrels of oil each at the start of drilling operations) has decreased steadily since 1940. There is no doubt that in this area nearly all the large oil pools have now been located, and with rare exceptions only small pools

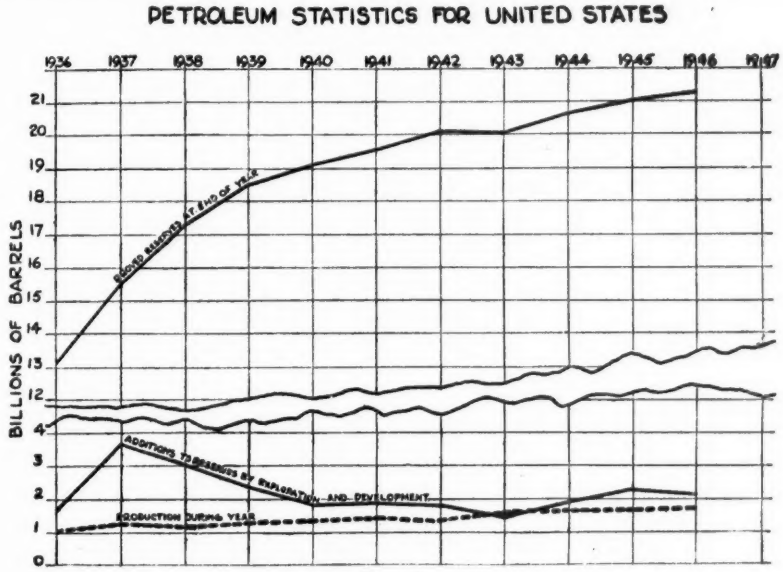


FIG. 3.

Billion = 1,000 million.

containing only a few million barrels await future discovery. Inasmuch as many of the more recent exploratory wells are deep tests, the more accurate presentation of results is expressed not by the simple number of holes drilled but by the relation between the number of feet drilled in exploratory holes and the number of barrels of oil discovered by the successful holes. The curve in Fig. 4, entitled 'New Proved Reserves per Exploratory Foot Drilled,' tells the story with impressive solemnity. Its decline from 1938 to 1946, compared with the increase in production from this 17-state area during the same years, is the crux of the problem, and fully justifies the gloomy prediction with

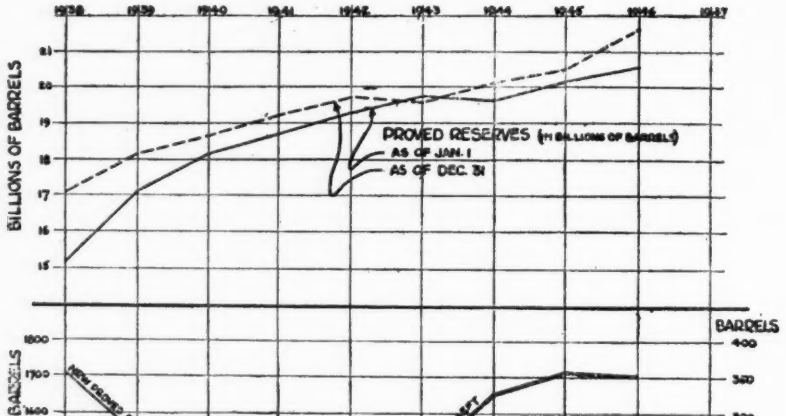

EXPLORATORY DRILLING AND PROVED RESERVES
IN THE 17 STATES THAT CONTAIN NEARLY ALL OF THE PETROLEUM RESOURCES OF THE UNITED STATES
BILLIONS OF BARRELS
PROVED RESERVES (IN BILLIONS OF BARRELS)
AS OF JAN. 1
AS OF DEC. 31
MILLIONS OF BARRELS
BARRELS
SCALE ON LEFT
SCALE ON RIGHT

FIG. 4.
Billion = 1,000 million.

which the preceding paragraph was closed. This, of course, is the inevitable story for every oil-producing region in the world. Although for a time a locality or a nation may profit greatly from the rich stores of oil within its bounds, sooner or later those stores will be exhausted. We are dealing with a non-renewable resource. We are burning up the capital provided by nature.

The United States is now enjoying the greatest petroleum production of all time. It is a safe expectation that the actual reserves of oil beneath its surface are two or three times the proved reserves of twenty thousand million barrels, but it is equally probable that its domestic production will fail to meet its needs within five or ten years from now. Production will probably be maintained at levels far above a thousand million barrels per year for thirty or forty years to come, but even such quantities will not be adequate to meet the steadily increasing demands.

Although we are prone to think of petroleum largely in terms of gasoline and diesel oil for internal combustion motors and of fuel oil for heating our homes and operating steam engines, the fact is that many other uses are now increasing the consumption of this most flexible of liquids. American farmers are not only using power machinery to a larger extent as the years go by, they are also using petroleum derivatives for insecticides and fungicides and many other purposes. Synthetic rubber, based upon butadiene derived from petroleum, is a war-time development, but it is here to stay. At many an oil refinery the butadiene storage tanks bulk large against the maze of pipes and towers.

Faced by this prospect of increasing demands and dwindling supplies, petroleum geologists, engineers and economists must employ every weapon in the arsenal of science and technology to meet the situation. Every barrel of oil brought to the surface must be used as effectively as possible. Much progress has been made in the last few years by the development of such refinery techniques as catalytic cracking, alkylation and the fractionating of the lighter compounds in the mixture of hydrocarbons comprising every crude oil. Research continues to blaze the trail toward the most efficient uses of natural

resources, always an important aspect of their conservation.

At the same time, every effort must be made to ensure the maximum production from the dwindling reserves. This involves two factors. First, there is the increase in percentage of recovery from oil pools after they have been discovered, by improved methods of production, such as maintaining the optimum gas-oil ratio throughout the life of a well, or by using such methods of secondary recovery as the water drive and repressuring by gas injection. Second, there is the discovery of new pools, either in new localities or by deeper drilling in old fields. This is the function primarily of the petroleum geologist, and it involves continuing research as well as the application of procedures already well established by long practice.

The importance of geology and geophysics is now well recognised throughout the entire industry in the United States, if not also in every other country. The statistics pertaining to the exploratory wells drilled in the United States in 1943 may be cited as illustrative of the reasons why geologists and geophysicists have established a secure place for themselves and may expect to continue their activities in the search for petroleum for many years to come. In that year, 3,843 exploratory wells were drilled. The location of 3,242 of these is known to have been selected on the basis of geological or geophysical surveys, or a combination of the two. Of these scientifically located wells, 626 proved to be productive. That is approximately, 20 per cent. were successful. Of the remainder, 523 are known to have been located by non-technical methods. Only 23 of these, less than 5 per cent., were successful. The method of determining the location of the other 78 wells is unknown ; 6 of them were productive.

It is, however, not to be expected that this excellent record of geological and geophysical achievement can be maintained in future years. Less favourable locations must be tested with the drill, if every oil pool, no matter how small, is to be discovered. A smaller percentage of successful wells to total exploratory tests is inevitable, as the search becomes concentrated upon stratigraphic traps and the doubtfully effective structural traps.

Accepting the fact that almost all the large oil pools within the land area of the United States have by this time been discovered, attention at the moment is being given to the possibilities of oil production from the submerged portion of the continent, known to geologists as the continental shelves. The coastal plain of Louisiana and Texas continues far out beneath the waters of the Gulf of Mexico, and the present position of the shoreline has no relationship whatsoever to the occurrence of oil beneath its surface. From the standpoint of geology there is no reason to doubt the presence of salt domes beneath the marginal waters of the Gulf, quite similar to those beneath the adjacent shore.

Petroleum engineers have already had considerable experience with drilling operations in shallow water. Hundreds of wells have been drilled in Lake Maracaibo, Venezuela, near its eastern shore. It is common practice to mount a derrick and drilling machinery on a barge which is navigated on the lakes and bayous of the Louisiana delta region and sunk to the bottom at the selected location for a well. But off-shore drilling in the Gulf of Mexico presents several new problems.

Geological conditions are revealed by geophysical surveys, which for the most part involve the use of portable seismographs and take advantage of modern methods of radar location. At each drilling site, piles are driven into the sea-floor to support the drilling platform which must be high enough above the water to escape damage from storm waves. Out in the open waters of the Gulf where hurricanes may occur, that means a height of something like 30 feet above high tide level.

The Magnolia Petroleum Company completed a dry hole in April of this year (1947) at a depth of 12,786 feet, in 16 feet of water at a point more than 5 miles distant from the nearest land. A second well, in 22 feet of water and 30 miles off the Louisiana shore, had been drilled to a depth of 2,613 feet in July. At that depth, the drill entered the cap of a salt dome, thus verifying the interpretation of the geophysical survey, as a result of which the drilling site had been selected. Other wells are even now in various stages of preparatory and drilling operations at distances of 10 to 40 miles from land.

Similarly, among the Bahama Islands and elsewhere on the continental shelf bordering the South Atlantic States, surveys have been in progress for nearly two years and drilling operations are scheduled to begin at an early date. Here, the gravity meter has been extensively used in the geophysical surveys. Many of the ingenious devices used in these underwater surveys are adaptations of equipment developed for military purposes during the war.

This extension of the search for oil to the continental shelf may confidently be expected to add a few thousand million barrels to American reserves, but it is an expensive project and at best will postpone by only

a few years the time when American production will lag far behind American consumption of petroleum products. Indeed, the probable production from this new source was included in the data upon which my forecast for the future was based in a preceding paragraph.

It is therefore appropriate to look next at the prospects for meeting the future needs of America by importing oil from other countries. As shown in Fig. 2, American interests control 75 per cent. of the nearly nine thousand million barrels of proved reserves in South America, more than 40 per cent. of the twenty-six thousand million barrels of proved reserves in the Middle East, and nearly 30 per cent. of the fourteen hundred million barrels of proved reserves in the Far East. Thus, if political factors are favourable the United States may draw upon nearly as many barrels of foreign oil reserves

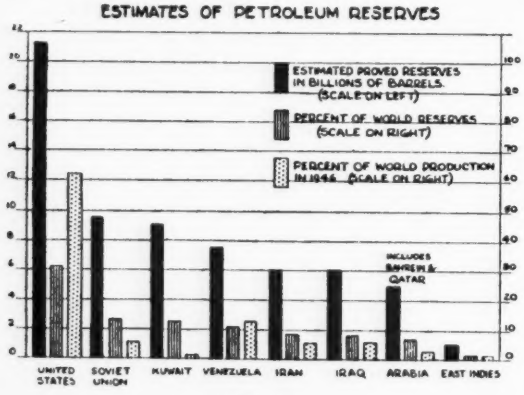


FIG. 5.
Billion = 1,000 million.

for its domestic needs as are presently available within its own boundaries.

But the United States does not exist in a geographical vacuum. It is but one among many nations having needs and rights with respect to petroleum. It is therefore imperative to consider this reserve from a world point of view. The broad features of the world picture are shown in Fig. 5, based upon the best estimates of proved reserves, made by competent geologists, as at January 1, 1947. In all probability, such a graph portraying conditions ten years hence would show a decrease in the proved reserves for the United States and an increase for every other country, with the possible exception of Venezuela, inasmuch as discovery and development have already advanced so much further in the States than elsewhere. One could almost venture the guess that whereas the actual reserves beneath the United States are probably not much more than twice the amount shown as proved reserves, the actual reserves in the other countries average at least three times the amounts shown for them.

Most amazing is the position of Kuwait, the tiny country at the head of the Persian Gulf, (see Fig. 6), exceeded only by the United States and the Soviet Union in the volume of its proved reserves of petroleum. I am, however, assured by Mr. E. L. De Golyer, who has studied the petroleum potentialities of the Middle East at close range, that the estimate of nine thousand million barrels for that country is very conservative. Significant also is the position of Iran, Iraq and Arabia as the fifth, sixth and seventh countries of the world, when the nations are listed in the order of their petroleum potentialities.

The most important inference, however, that should be drawn from this picture is based upon a comparison of the two percentage columns shown for each country. Whereas the United States possesses only a little more than 30 per cent. of the world reserves, its production has been running well over 60 per cent. of the world production each year. Venezuela is the only other country, possessing more than a thousand million barrels of proved reserves, in which the percentage of world production in 1946 exceeded the percentage of world reserves. The deduction is obvious : if present trends continue, ten to twenty years from now, the United States will be a ' have-not nation ' so far as petroleum is concerned ; the ' have nations ' will be the Soviet Union, Kuwait, Iran, Iraq, Arabia and the East Indies. It is no accident, that practically all of the potential oil fields of the five last-named countries are under the control of American, British and Dutch corporations.

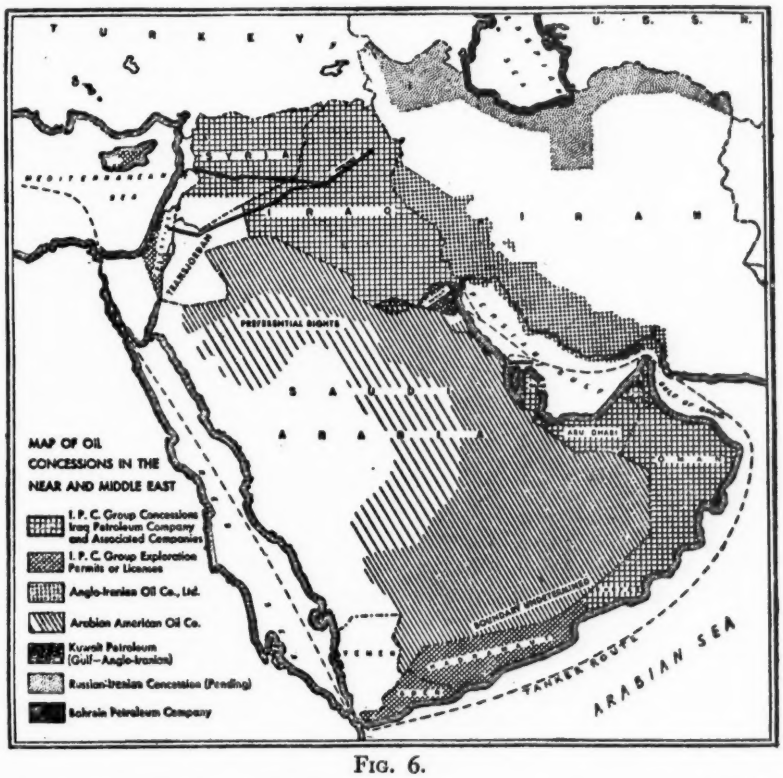
This raises the question of the adequacy of the world's supply of oil for meeting the future world demands for petroleum products. At the moment, world consumption of petroleum is running at an annual rate of approximately twenty-eight hundred million barrels. That is 4 per cent. of the world's proved reserves and something like 1 per cent. of the world's actual reserves. Demands are certain to increase greatly in the next few years, not so much as a result of increase in world population, but because of increased consumption by people who have not hitherto been large consumers of petroleum products. Whereas, for example, the annual peacetime consumption of petroleum within the United States is 450 gallons per capita, in the United Kingdom it is 80 gallons, in the Soviet Union, 50 gallons, and for the world as a whole, other than the United States, it is only 15 gallons per capita. This marked disparity is certain to be reduced in the future by a great increase in the per capita

consumption of petroleum products outside the United States.

Even so, it would appear that world petroleum reserves are quite adequate to meet world needs for half or three-quarters of a century to come. But that will mean almost complete freedom for distribution of the oil and its products from the regions of supply to all parts of the world, regardless of political boundaries. Never was there more convincing evidence of the fact of mineral interdependence in the modern world, a fact that should be thoroughly comprehended by every person concerned with international relations. In all probability, the optimum distribution of the abundant, but locally concentrated supplies of petroleum can best be attained by some sort of voluntary allotment or quota system, established and maintained by agreements among the nations and corporations possessing or controlling the sources of supply and the means for discovery, extraction and transportation of the oil.

There are, however, two reasons why alternative sources of gasoline, diesel oil, fuel oil and lubricants are even now being sought. One is the fear that political and economic barriers may be raised against the free flow of oil from South America and the Middle East to the United States, a few years hence, when American production fails to meet American needs. A variant of that fear is probably present in Great Britain, as one contemplates the dependence upon foreign oil fields and the possibilities of a future war. Despite the superb ingenuity responsible for the discovery of the small oil fields in Nottinghamshire, there is absolutely no possibility of finding sufficient oil in the British Isles to meet more than a very small fraction of the needs. The other reason is the fact that it is by no means too early to begin preparing for the inevitable day, which will probably come before the end of the present century, when world production of oil will be inadequate for world needs.

Already, an appreciable fraction of American requirements for petroleum products is being met by the synthesis of liquid hydrocarbons from natural gas. At the moment, a pilot plant for the synthesis of petroleum from oil-shale is being completed and put into operation in Utah by the U.S. Bureau of Mines. Methods of synthesising petroleum products from coal, developed by German scientists before and during World War II, are being checked and improved in the research laboratories of governmental bureaux and of private corporations in the States. The success of the oil-shale industry in West Lothian, and the great quantity of synthetic gasoline that helped so materially in providing power for the German war machines are a sufficient guarantee that science and technology have provided an alternative source of supply, long before the petroleum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Kuwait Petroleum (Gulf–Anglo-Iranian)
Russian-Iranian Concession (Pending)
Bahrain Petroleum Company

FIG. 6.

resources of the world have even begun to approach exhaustion.

And these alternative sources are almost unbelievably abundant. In the United States alone, there is enough oil-shale and coal available to provide the equivalent of two thousand million barrels of crude oil each year for at least a thousand years. Similarly, if known techniques of producing petroleum products from coal by chemical synthesis were applied to the coal reserves of Great Britain, all British requirements for such products could be met for at least a few hundred years.

But such application of technical knowledge is not by any means an easy and simple matter. Processes now available are too expensive to permit competition with natural petroleum products except under extraordinary conditions, such as those that make the Scottish and Swedish oil-shale industries economically feasible. The necessary equipment is extremely complicated, very costly, and requires extensive plants. Its installation is not practical on a sufficiently large scale to permit such a substitution of mineral fuel sources in the immediate future.

Nevertheless, there is every reason to expect the gradual replacement of natural petroleum products by synthetic products in the more distant future. As the supplies of crude oil are exhausted, this alternative source will take their place. Thanks to science and technology, the mineral fuels stored within the earth will prove adequate for all human needs for as long a time as they are needed. Long before the oil-shale and coal are exhausted, still other sources of energy, such as the atomic energy released by nuclear fission, will be available to do the work that men want done.

Far more difficult than the technical problems involved in meeting the physical needs of humanity are the psychological and spiritual problems that retard the process of learning how to live properly in a world community. Perhaps knowledge of the fact that our small world is a world of potential abundance but inescapable interdependence, as illustrated by such an inquiry as this concerning one typical, non-renewable resource, may help to accelerate that learning process.

The author is deeply indebted to Mr. R. G. Watts of the Magnolia Petroleum Company, Mr. W. H. Wilson of the Humble Oil Refining Company, Mr. George Krieger of the Ethyl Corporation, and Mr. Roy. E. Stryker of the Standard Oil Company of New Jersey for information and photographs used in the presentation of this paper as an illustrated lecture. The data pertaining to proved reserves of petroleum in countries other than the United States are based upon statistics published in the 1947 edition of the Petroleum Report prepared by De Golyer and McNaughton. The record of drilling operations in the '17-state area' of the United States was compiled by Dr. F. H. Lahee and his Committee on Exploratory Drilling, of the American Association of Petroleum Geologists.

CAMOUFLAGE [1]

BY

DR. HUGH B. COTT

CAMOUFLAGE is the art of baffling hostile observation. It is a means of misleading the enemy by visual devices. In war, its function is essentially to present the observer—whether on the ground or in the air—and the photographic interpreter, with false information. By its successful employment it is possible not only to save lives, material and equipment for subsequent use, but also to bewilder the enemy, causing him to make false moves, to waste his bombs and ammunition, and to dispose his forces in the way best suited to our plans.

[1] The text of an Evening Discourse delivered to members of the Association on Sept. 1, 1947, at the Annual Meeting in Dundee.

The methods by which camouflage is achieved, though very various, and though applicable to all arms and services, to all types of terrain, and to different tactical situations, fall into three main groups: firstly, concealment, whereby a target is made difficult or impossible to detect; secondly, disguise, whereby the target is made to resemble an object having some other than its real significance; and thirdly, display, in which false targets or dummies are made to appear like real objects of significance in war. Frequently it happens, as I shall show later, that all three methods are combined in an operation. But whatever the technical devices used, the end is fundamentally the same

—to frustrate observation and intelligence, by so controlling our behaviour in the theatres of war, that the enemy will assess our activities as we wish.

In a search for guiding principles, we cannot do better than turn to nature, taking advantage of advice which you will find in the Book of Job : ' But ask now the beasts, and they shall teach thee ; and the fowls of the air, and they shall tell thee . . . and the fishes of the sea shall declare unto thee.'

Interspecific warfare is one of the fundamental facts affecting the lives of wild animals. Individual survival in nature depends upon the satisfaction of two basic needs—food and safety. It is the age-old problem of the relationship between aggressor and victim, between predator and prey. The severity of the struggle for existence is reflected in the extraordinarily elaborate adaptations found among animals. And here, may I remind you of the very interesting fact, that there is a close analogy between the adaptations of animals and the inventions of man—whether used in nature or in battle. Indeed, almost every invention, including some of the most recent, has its counterpart in the modifications and behaviour of various wild creatures. To realise the truth of this we have only to think of the use, by squids, of jet propulsion and smoke screens ; of poison gas, by skunks and many insects ; of chemical warfare by various termites and by the Ringhals Cobra of tropical Africa ; of armour, by tortoises and armadillos ; and of the recently discovered system of echo-location in bats, which shows us that the principle underlying radar has been in practical use by these animals doubtless for many millions of years.

Among the various adaptations of animals, used for pursuing prey or eluding enemies, and each having its parallel in the equipment of modern warfare, perhaps none is so important, so widely employed or so perfectly developed, as the use of those devices which serve for concealment, for disguise, or for bluff. Indeed it is perhaps true to say that these modifications of appearance and behaviour are among the most striking achievements of organic evolution.

It is my intention to discuss the optical principles upon which camouflage depends ; to indicate the methods by which it has been attained in nature ; and to refer to the bearing of these principles and devices upon the practical problem of applied camouflage.

Before considering the methods by which an animal or any other object can be rendered inconspicuous or difficult to recognise, we must be quite clear as to the nature of various optical clues which make recognition possible. When we look at an opaque body, it appears in the field of vision as a patch of colour, differing more or less from surrounding objects which form its background, in colour and tone, in light and shade, in shape and contour, and revealed further by the form of its shadow. It cannot be too strongly emphasised that visible form can only be distinguished when it is exhibited by differences of colour and tone, or of light and shade. With progressive reduction of such differences, an animal or any other object becomes more and more difficult to recognise : in their absence, it becomes unrecognisable.

It follows from these considerations that four fundamental steps towards effective concealment must lie in the direction (1) of colour resemblance—or the agreement in colour and tone between the object and its background ; (2) of obliterative shading—a system of counterlightening and darkening which abolishes the appearance of relief caused by the effects of light and shade ; (3) of disruptive coloration—or the use of a superimposed pattern of contrasted colours and tones which serve to break up surface continuity and to blur the outline ; and (4) of shadow elimination—the screening or effacement of cast shadows by orientation or by structural means.

It is a significant fact that these theoretical principles, together with various associated devices and instincts, are those actually applied in nature, whereby different animals —belonging to most diverse groups and living in the most dissimilar surroundings—are rendered so extraordinarily difficult to detect when encountered in the field ; and it is upon these principles that every effective scheme of applied concealment must be based.

One further point should be emphasised at the outset, namely, that it is only when animals are studied in the wild state, that it is possible to appreciate the significance of the colours and patterns which they wear—for only then can the various devices be considered in relation to particular postures, habits and backgrounds, and to the habits of enemies and prey. Of the utmost importance, in this connexion, is the habit possessed by most cryptic forms of remaining motionless when in danger, and thus escaping detection in circumstances where the least movement might betray their presence.

General Colour Resemblance

The general resemblance borne by various animals to the different surroundings in which they live is a theme more or less familiar to everyone. Each major environment with a dominant type of coloration furnishes innumerable examples—various members of the fauna wearing a cryptic dress or uniform—

immaculate white in the snowlands ; ochre, buff or sandy-grey in the desert ; green among the ever-green foliage of tropical rain forests ; dull and dappled beneath the trees ; striped among grass or reeds ; blue, or transparent, in the surface waters of the sea.

It is interesting to notice that in a given environment similar cryptic colours have been evolved independently in the most distantly related groups of animals ; and in the most widely separated geographical areas ; while the coloration itself is due to a variety of causes. For instance, among foliage dwellers, green coloration has been adopted as a uniform by many families of snakes and lizards, tree frogs and birds, as well as by innumerable caterpillars, grasshoppers, cockroaches, moths, mantids, beetles, bugs and other insects. It is found in similar environments in South America and Australia, in tropical Asia and tropical Africa. It is produced in some cases by green pigment ; in others as a structural colour ; or by a combination of both effects ; in others again by the colour of the green food showing through a transparent body wall ; or by the adventitious use of algæ, as in certain crabs.

An interesting question bearing on the nature and quality of light reflected from green animals is opened up by the technique of infra-red photography. It is well known that the chlorophyll of leaves reflects light in the infra-red region of the spectrum, and that consequently grass or foliage appears snow-white in the infra-red photograph. But different green animals, which to the eye appear similar in tone and colour both to one another and to their surroundings, differ greatly in their absorption of infra-red light. It follows that when twin photographs are taken on panchromatic and infra-red plates, the results in certain cases are most revealing —those forms which absorb infra-red rays becoming in the latter strongly differentiated from the background, and appearing as dark objects standing out conspicuously from their light surroundings.

The practical importance of the subject is obvious, since infra-red air photography may be of great value in the detection of a camouflage scheme that would pass muster visually or in the panchromatic photograph. It is interesting to find that this difficulty can be met, and has been solved in nature—as may be seen, for example, in the green tree frog *Hyla caerulea*. For here the skin, whose green colour is due to a combination of chemical and physical effects, behaves in the infra-red photograph like the chlorophyll of its background, to which it has no chemical or physical affinity whatever. Thus the harmony of tone upon which inconspicuousness depends is retained, the frog appearing in waxy-pallor amidst snow-white foliage.

That colour resemblance does in fact confer a vital benefit upon its possessor, in the struggle for existence, has been abundantly demonstrated by recent experiments—notably those of Lee R. Dice, F. B. Isely and F. B. Sumner in America, and of R. Carrick and E. J. Popham in this country. Working with various predators, such as fish, penguins, owls, and insectivorous birds, these observers find that in a mixed population of prey—some of which blend with their background while others differ from it—the latter tend to be captured much more frequently than the former.

The importance of colour harmony is also reflected in the behaviour of many animals. I must refer here to the most interesting observations of R. Meinertzhagen and G. Niethammer, on the very clearly defined habitat-preferences of certain desert larks. Not only do various species and races of *Ammomanes*, *Mirafra* and *Spizocorys* closely resemble the colour of the particular ground on which they live, whether black lava, or brown, red or white sand ; but also the birds are extremely reluctant to leave their own terrain. Thus in the Syrian desert Meinertzhagen found that nothing would induce the black larks inhabiting black lava hills to settle on the adjacent yellow sands.

This principle of colour resemblance, simple as it is, was not always appreciated by the authorities ; and during the early fighting in the Western Desert quantities of green hessian (of a type suitable for green country) were sent out to the Middle East for the garnishing of camouflage nets intended to effect concealment against the nearly white sand of the desert. Similarly bren carriers came out equipped with a camouflage net disrupted with a pattern of black and dark green.

Obliterative Shading

The second optical principle upon which concealment depends is that of countershading. Owing to the effect of unequal illumination, a solid body of uniform colour presents to the eye the well-known appearance of light and shade, or relief, to which is mainly due its appearance of solidity. By this means alone, an object can be distinguished as a solid form—even when it is placed before a background whose colour and texture exactly matches its own.

When an animal or any other solid object is observed out of doors, it will be seen that its upper surface is more brightly illuminated than its underparts, owing to the direction of incident light from the sky. The effect of this top lighting is to brighten the upper

surfaces, while the lower surfaces which are in shade appear to be darkened.

By countershading the upper surfaces, and by counterlightening those beneath, using properly graded tones on the sides, it is possible to counteract these effects of light and shade, and thus to render a rounded body apparently flat. If properly carried out, this treatment by countershading absolutely obliterates relief, and renders the object completely invisible from a short distance, provided it is viewed against a suitable background. It will be noted that such a result is brought about by the use of tones which are darkest above, becoming gradually lighter on the sides, and lightest beneath.

The theory of concealment by countershading will always be associated with the name of Abbot H. Thayer, the American artist and naturalist, who first fully grasped this important optical principle, which operates so widely in the coloration of different animals. Countershading has been used with remarkable effect for the concealment of many creatures : the brush of nature has laid down in skin and scale, fur and feather, darker pigments on the back, grading into paler pigments on the belly, as seen in the coloration of many marine and river fishes such as Tunny and Trout, and of the majority of land animals and birds, and of innumerable insects.

In countershading we have a system of coloration the very opposite of that upon which the artist depends when painting a picture. The artist, by the skilful use of light and shade, creates upon a flat surface the illusion of solidity : nature, on the other hand, by the precise use of countershading, creates upon a rounded surface the illusion of flatness. The one makes something unreal recognisable ; the other makes something real unrecognisable.

The applications of this principle to war camouflage are obvious. The conditions of light which affect the appearance of a caterpillar or snake are the same as those which cause a uniformly coloured gun barrel or torpedo tube to stand out conspicuously, even when seen against a background covered with exactly the same paint. It is therefore important to treat such rounded objects with paint so applied as to counteract the effects of relief.

Although the principle was well understood by biologists several years before the outbreak of war in 1914, its application was still ignored in some quarters in 1939, when as you will remember from photographs published in the press, camouflaged coastal defence and naval guns were decorated with a design, then favoured by the authorities, which entirely missed the mark.

It so happened that just after the outbreak of war I was allowed, at the invitation of the Royal Engineers Signal Board, to demonstrate the method by countershading a battery of heavy 9·2 in. railway guns in this country. Owing to the need for mobility, paint was to be the only camouflage protection used in the experiment. When I first saw the 4th Super Heavy Battery, the pieces and mountings had been treated with a somewhat zebra-like pattern of green and black stripes. I will not weary you with details of the design later applied—a design which for effective treatment demanded the maximum range afforded by paint, from mat black above to pure white below, suitably graded round the sides of the piece and incorporating an additional disruptive pattern.

The scheme was intended to reduce the distance from which the battery would be visible from hostile aircraft. The gunners were well-satisfied with the result. The R.A.F. subsequently carried out a reconnaissance flight over the area, and reported that the countershaded gun was first recognised from a height as low as 2,000 feet. This compared favourably with about 10,000 feet in the case of the original paint-scheme. The experiment thus fully justified our faith in the soundness of the basic biological principle involved.

In nature, the occurrence of obliterative shading is closely correlated with the habits of the animals concerned. Thus it is of particular interest to notice that different cryptic animals which habitually rest in an inverted position, have the normal colour scheme also turned upside-down, that is to say—they are coloured lightest on the back and darkest on the belly. A beautiful example among British insects is furnished by the larva of the Eyed Hawk Moth.

Disruptive Coloration

We now come to what is perhaps the most interesting, and certainly the most important set of principles relating to concealment by colour—namely, the type of camouflage properly known as Disruption. It will be clear from what has already been said, that under ideal conditions, colour harmony combined with countershading are alone sufficient to render an object virtually invisible. But in nature, as in war, conditions are rarely ideal, for they constantly change ; and we have to reckon with variations both of background and of lighting. Objects therefore tend to present to the eye continuous patches of colour, differing more or less from their background, and outlined by characteristic shapes or contours. It is this continuity of surface, bounded by a

specific contour, which provides the chief clue to recognition : and it is therefore essential to destroy the tell-tale appearance of form.

This difficulty is met by the application of principles involving the use of patterns, such as those exhibited on the bodies of boa constrictors, bitterns, various frogs, grasshoppers, moths and many other animals. The function of a disruptive pattern is to prevent, or to delay, the first recognition by sight. Its success depends not only upon optical principles but upon a psychological factor. The irregular patches of contrasted colours and tones with which such animals are marked tend to catch the eye of the observer, to distract his attention from the underlying form upon which they are superimposed, and to be accepted as incidents in the background.

If the design is to be effective, the colours, tonal contrasts, and patterns used must conform to certain definite principles ; and once again we find that the particular devices which on theoretical grounds appear best for this purpose, are those which take effect on the bodies of innumerable animals that rely for safety, or for obtaining food, on concealment.

In the first place, concealment is greatly enhanced when some of the components of a disruptive pattern match the background, while others strongly differ from it. Under these conditions, by the contrast of some tones and the blending of others, some portions of the object fade out completely, while others stand out emphatically, and it is to be noted that the shape of the latter—which alone can be distinguished—is such as to contradict the underlying form.

The second of these principles has to do with the degree of tonal contrast between adjacent elements in the pattern. We have seen that the effect of disruption is to break up what is really a continuous surface into what appear to be a number of discontinuous surfaces. These tend to be interpreted by the eye as separate objects. This illusory appearance—this contradiction of the true form—is greatly strengthened by the use of violently contrasted tones. The effect is further enhanced when the tones of greatest contrast—that is to say, those representing the highest lights and the deepest shades—occur adjacent to one another : when, in other words, the transition is abrupt, without intermediate gradations or half tones. In nature this arrangement of the elements in a pattern is applied with remarkable effect in the coloration of many snakes, such as the Gaboon Viper, of birds, such as the young Ringed Plover, and of many reef-dwelling fishes and other animals.

There remains to be mentioned a further expression of the disruptive principle which is of considerable interest. Such patterns as we have so far considered are successful because they appear to break up the continuous surface of the body. Now this visual device is carried a stage further in the case of many animals in which the pattern appears to join together separate parts of the body. One of the factors leading to recognition of a particular object, such as an animal in nature, is the familiar appearance of structural features—for instance, legs, fins, eyes and wings. If, however, the elements of the pattern sweep without interruption across the various parts or organs, the latter are less likely to attract notice.

The principle is well illustrated in the colour scheme of a small East African tree frog *Megalixalus fornasinii*. This animal bears on its back a pair of broad, conspicuous, silvery-white stripes. Similar stripes occur on the hind limbs. Now these markings are so disposed, that in the normal resting attitude (when the limbs are closely applied to the sides of the body) the stripes on the back exactly coincide with, and become a continuation of, those on the legs. This attitude and striking colour scheme thus combine to produce an extraordinary effect, whose deceptive appearance depends upon the breaking up of the entire form into two strongly contrasted areas of dark brown and white. Considered separately, neither area resembles part of a frog. In the field, the white element alone is conspicuous, and this stands out to distract the observer's attention from the true form of the body and appendages.

Similar coincident patterns occur widely in nature, and are used to span the spaces between the folded segments of the leg in many frogs ; between the wings and body in grasshoppers ; between the fore and hind wings in various cryptic butterflies, or between the upper and lower jaws in certain snakes and lizards. In all such cases, the pattern cuts right across existing structures, thus contradicting the underlying anatomy and creating an illusion of continuity. You will observe that the principles of disruptive, and of coincident patterns are quite opposed —the first breaking up a continuous surface, the second uniting discontinuous surfaces : but that both combine to disguise form.

A special application of this principle is seen in the camouflage of the eye itself. A circular object such as a fish's eye is inherently conspicuous, and it is not surprising to find that nature has taken special steps to obliterate what would otherwise be a tell-tale target. Here the method, employed by many fishes, frogs, snakes, birds and other animals, is to include the black pupil within a stripe or

band of black pigment, which typically sweeps unbroken across the iris, so that the eye becomes incorporated and lost within the general pattern of the body.

The considerations which I have put before you provide us with a ready means of reducing the visibility of potential targets in war. Given a thorough grasp of the principles, their scope of usefulness and their proper application become obvious enough—whether the problem is to conceal a small object, such as a vehicle, or a large one, such as a landing ground or factory installation.

During the Second World War, the defensive concealment of civil factories and the elimination of landmarks were the responsibility of the Ministry of Home Security: these are aspects of camouflage somewhat outside the scope of this address. This large-scale static work—of such vital importance to the war effort—was carried out under the skilled direction of Wing-Commander T. R. Cave-Browne-Cave, who was Director of camouflage and Chairman of the Camouflage Committee set up to co-ordinate camouflage within the civil and fighting services.

Disruptive methods have of course a special application in the painting of ships. The distractive value of a vigorous pattern, familiar from its wartime uses under the somewhat unsatisfactory term 'dazzle,' is now generally recognised. It was Sir John Graham Kerr who in September, 1914, first suggested to the Admiralty this practical means of diminishing visibility and vulnerability at sea. Copies of his letter were circulated to the Fleet in the following month. Unfortunately some of the early experiments with paint failed to take effect, since much of the work was done without the guidance of competent scientific experts—being left to the discretion of individual officers who sometimes failed to appreciate the optical principles involved.

Dazzle painting of surface vessels was intended as an added protection against submarine attack, and had for its main object the visual distortion of the hull and upper works by violently contrasted patterns—in order to disguise perspective and consequently the course and speed of the vessel, accurate knowledge of these factors being essential to successful attack. In the First World War, upwards of 5,000 ships were treated in this way, and the success of the method was recognised in an Admiralty memorandum of December 1917, which stated that 'The scheme of painting now in force has fully justified its adoption and trials have demonstrated the difficulties of correct aim even when the ship's approximate course was known.'

Disruptive patterns may be applied to the surface of solid bodies for two fundamental purposes—namely, for the disguise of surface; and for the obliteration of contour. Hitherto we have dealt with the first of these functions. We have yet to consider briefly the problem of the contour, which is one of great importance, since a familiar outline or silhouette is one of the main factors upon which recognition depends.

Many years ago, Dr. J. C. Mottram showed, in a paper published in the Proceedings of the Zoological Society of London, that outline obliteration is induced when contrasted elements in the pattern are interrupted at, or near, the margin. Conversely, the contour is emphasised when the pattern conforms to it. The essential point is that for purposes of concealment the pattern should cut across, rather than run along, the outline. The principle involved can at once be appreciated by comparing similar bodies bearing the two types of pattern. When such bodies are examined from successively increasing distances, it will be found that the contour of one blends with the background at a point from which the other is still plainly visible. Patterns of this kind, which run across, and are interrupted at, the margin, occur in many classes of animals such as the Zebra and Giraffe, and many fishes, butterflies and moths, and play an important part in reducing visibility.

I now come to a second method of disguising the outline. There are certain characteristics of the contour of animals, such as regularity of form, repetition of detail, and symmetry, which greatly facilitate recognition. It follows that any device which destroys or subdues these properties will increase the difficulty of detection. This problem may be met by the modification of the contour itself—a method actually employed by many of the most perfectly camouflaged animals. In the cases dealt with hitherto, the outline is obscured visually by an interrupted marginal pattern; in those now under consideration, it is effaced structurally by an irregular marginal form. The first system depends upon optical illusion; the second upon structural modification.

This method is beautifully illustrated by the Comma butterfly, whose outer wing margins are highly irregular in form, and give the insect a very cryptic appearance in the field. Similarly, various fishes and tree geckos have the outline wonderfully disguised by weed-like or bark-like outgrowths from the sides of the body.

Shadow Elimination

In the patchwork configuration which the eye sees in nature, shadows take a prominent

place. Under conditions of intense illumination, the shadows cast by different objects may be both conspicuous in tone and distinctive in form. Indeed, in the case of cryptic animals, the shadow may in general be more conspicuous than the animal which casts it. And I need hardly remind you that in the reading of air photographs, shadows are among the most significant features available to the interpreter.

Various butterflies, such as the Grayling, which habitually rest on the ground, with the wings closed over the back, orientate the body in relation to the sun on alighting, so that the shadow cast by the wings is reduced to a mere inconspicuous line. In this position the insects are extremely difficult to detect, for the exposed surfaces of the wings bear a disruptive design which harmonises closely with the surroundings ; and there is evidence that these insects even defy detection by such keen-sighted birds as Kestrels.

As a further adaptation tending to conceal the shadow, when seen from above, certain butterflies exhibit the remarkable instinct of tilting the body and wings over to one side in a pronounced list. The effect of this habit is to bring the cryptic wings over as a screen to cover the shadow which they cast. Many other animals meet the difficulty by crouching flat, with the body or wings closely applied to the surface on which they are resting. This arrangement is beautifully illustrated by the young Stone Curlew and other birds, and by bark-dwelling moths such as the Willow Beauty, whose attitude is such that the shadow is entirely screened beneath the outspread wings, which themselves closely simulate, in colour, pattern and alignment, the surrounding bark.

A further development of the same principle is seen in certain tropical tree geckos, where the squatting habit is greatly enhanced by flap-like outgrowths which, extending from the sides of the body and tail, serve both to screen the shadow and to join the body to the tree trunk, which it closely resembles, so that the animal appears to form part of its natural resting place.

Many years ago Sir Edward Poulton pointed out that certain twig-like caterpillars, such as those of the Early Thorn and Brimstone Moths, appear to grow out of the twig on which they rested. This effect depends largely, as he showed, upon the obliteration of the shadow between insect and plant, and is due to a number of fleshy tubercles which, being light in colour, neutralise the shaded furrow which might otherwise betray the junction. Once again, all these various devices for shadow concealment find a wartime application, as seen, for example, in the use of camouflage netting, suitably garnished according to local conditions of colour and texture, and so disposed as to merge the target into its surroundings.

Background Picturing

We now come to another aspect of concealment, particularly applicable to animals which habitually rest upon specialised surroundings. The patterns hitherto considered break up an animal's form into a number of more or less contrasted patches of colour, whose shapes are arbitrary. While they fail to suggest the form of the body displaying them, they do not necessarily simulate anything else in particular. A further step towards invisibility is taken when the disruptive design more or less closely reproduces the background-pattern against which it is seen—as happens, for instance, in the case of many cryptic moths, birds and fishes. Such animals carry on their bodies the detailed picturing of their normal habitat—of bark or lichen, of grass or heather, of coral or seaweed—and thus, when motionless, easily escape detection. Such colour schemes differ from the disruptive type in being specific or scenic, rather than abstract or arbitrary.

A remarkable instance came to my notice many years ago on the Lower Zambesi, when a hawk moth known as *Xanthopan morgani* was seen at rest on the trunk of a casuarina tree. The pattern of the wings exactly reproduces that of the bark, and the moth instinctively rests with its body in a vertical position, thus bringing the pattern into alignment with that of its surroundings. Of even greater interest, however, are those cases in which a similar effect is arrived at by adaptive orientation of the body. Many moths, such as the Mottled Beauty and Spring Usher, have the disruptive elements in the pattern so disposed that when the wings are in the resting attitude, the dark shadow-markings run across at right angles to the body. When seen against a background of bark, such an insect would appear less conspicuous if it were to turn round so as to bring its body at right angles to the axis of the tree trunk. Now the interesting fact is that such moths do habitually rest in this very attitude, which once again aligns the pattern to its natural setting. The same principle is seen at work when a Bittern adopts its well-known cryptic pose with its beak pointing heavenwards, so as to bring the striped pattern of its throat and breast into line with the background of reeds which form its home.

A consideration of these devices leads us inevitably to a system of applied camouflage which attained a high degree of perfection during the recent war and which depends upon siting and the correct use of ground-

pattern. In modern warfare, deceptive schemes have to be adapted so as to defeat air reconnaissance and the interpretation of air photographs. During the early months of the First World War, before air attack and air reconnaissance had seriously to be reckoned with, concealment from the air was neglected. The operational areas soon became transformed by the presence of battery positions with their associated blast-marks, vehicles and tracks, of ammunition dumps, signals communications, vehicle parks, and innumerable other signs of military activity, which inevitably superimposed a new visual pattern, the pattern of war, upon the original landscape. Each installation and arm, moreover, had its own characteristic lay-out and associated features, so that its nature would be immediately recognisable from above.

With the evolution of air warfare, all this had to be changed. The old conventional methods of siting and lay-out had to be modified, in favour of methods which utilised to the utmost extent existing features in the ground-pattern as seen by the air observer or photographic reader. Training in the proper use of ground for concealment from this new view-point became of paramount importance. And the understanding and practice of siting and track discipline formed an essential part in the training of officers and other ranks of all arms passing through the various camouflage schools. The aim was now so to control the activities of an army as to disturb as little as possible the original appearance of the area.

Deception by Disguise and Display

Many animals have gone a further step along the road towards self-effacement, and obtain protection by special resemblance to some seemingly innocuous object—such as a leaf or twig, a stone or piece of seaweed, a flower or the dropping of a bird—which is of no interest to their enemies. In short, they make use of the principle of disguise, whereby their real identity is hidden. You will be familiar with examples among insects and other animals, and I will confine myself to a few illustrations to remind you of the astonishing effects which have been produced by modifications in the appearance and habits of certain insects, reptiles and other creatures.

Perhaps the climax is reached by certain ants, belonging to the genus *Colobopsis*, whose habits have been described by Forel. These insects nest within hollow bamboos, and hide the entrance to their home in a remarkable manner. The duty of porter is performed by a special caste of large individuals having the head specially modified as a bung or stopper, being circular and truncated in front, and perfect even as to colour, for the frontal part of the janitor's head imitates the appearance of the stem in which the nest is situated.

In the Western Desert, bren carriers operating in a role which demanded surprise or ambush, were totally concealed by this very method, being housed in a pit cut into the side of an escarpment, the entrance to the pit being covered with a tarpaulin garnished with sand.

Such, then, are some of the methods of concealment and disguise. We have yet to consider briefly another system of camouflage, the very reverse of the methods so far described, and one which depends upon the display of dummies designed to give a false impression to the enemy of our dispositions, strength and intentions. Once again we find that various animals have exploited such possibilities of deception. A number of defenceless forms carry on their bodies conspicuous patches of local colour, whose function is to deflect the attack of enemies from the more to the less vital parts. Frequently such markings take the form of dummy eyes, or ocelli, placed near the hind margins of the wings in butterflies, or the bodies of fishes, the real eye of such species being either hidden from view, or concealed by specialised disruptive patterns. In such cases, experimental and observational evidence tends to show that the fake eyes do in fact mislead enemies, and misdirect attack towards non-vital parts of the body, thus increasing the chances of escape by flight.

The same principle is well illustrated by the Ptarmigan. Here the change from white winter plumage is deferred in the male until the females in their cryptic summer dress have completed incubation. As a result, the males become relatively much the more conspicuous sex during the nesting period, and tend to deflect attack by birds of prey towards themselves and away from the more valuable and vulnerable females, while the latter are engaged with domestic duties.

Such devices have many wartime applications, in the employment of dummy and decoy positions small or large, as seen for example in the use of decoy fires and other installations whose function was to deflect bombs in a night raid away from the real objective on to a false one.

A further deceptive principle—again with many obvious applications—is based upon bluff, or a false show of force. Naturalists are familiar with examples of the kind—such as the Australian Frilled Lizard, with his menacing display, and various hawk moth caterpillars which on provocation inflate the anterior segments of the body so as to expose two large dummy eyes resembling those of a snake.

For purposes of offence and the capture of prey, other animals have perfected the disguised approach. The ' Peche de Folha ' or leaf-fish (*Monocirrhus polyacanthus*) is an inhabitant of the Amazon. Not only is this creature itself astonishingly leaf-like both in colour and form, but its habits are such as to confirm the deceptive appearance. It has a wonderful capacity for floating motionless in backwaters where—suspended on its side, or at an angle, or head downwards, or resting lightly on the bottom—no visible swimming movement betrays its real identity. It subsists solely upon small fishes ; and when feeding, the leaf-fish drifts slowly towards the selected victim, until close enough to dart forward, extend its huge mouth, and engulf the unsuspecting quarry.

Operational Camouflage

In operational camouflage, a combination of these methods is used on a vast scale, so as to mislead enemy intelligence. As an example, I may mention some of the devices used to deceive the enemy before the battle of El Alamein. In the northern sector, where the main offensive was to be launched, the forward positions eventually to be occupied by the armoured divisions were filled up gradually by dummy and real transports on the same scale as the assaulting formations. The enemy was thus allowed the impression of a forward concentration of vehicles, but of no armour. In the meantime, the real armour assembly behind at the staging area was disguised by an ingenious device—the direct invention of Lord Wavell—by means of which each tank resembled a transport. When, under cover of darkness, the disguised tanks moved up into their forward positions, their counterparts were brought back to take their places in the staging area. In this way complete concealment of the armoured divisions was achieved.

Artillery was likewise disguised, each of some 350 twenty-five pounder guns with their limbers being disguised to resemble a truck by means of a light superstructure of poles and hessian, so that air reconnaissance would reveal vehicles, but no guns. Gun pits were dug to resemble vehicle pits. No calibration was allowed and the enemy was unaware of this concentration of artillery. Forward dumps of petrol and ammunition were concealed by various means : on suitable ground hiding by siting was adopted ; elsewhere, old weapon-pits and vehicle-pits long known to the enemy were used as stores ; in more open and featureless areas, stores were erected into shapes which resembled lorries, mingled with real vehicles to give the necessary appearance of real activity in the area.

While these preparations were taking effect in the northern sector, the impression of an impending southerly thrust was created by an extensive display scheme in the south. This involved the use of dummy guns at staging points, and of other dummy guns mingled with real artillery in forward areas. Innumerable other signs of preparation were simulated. The scheme required much careful organisation and stage management. It included the construction of a dummy pipe line, with dummy pump houses and reservoirs, the work proceeding at normal engineer rate ; the laying down of dummy stores built to resemble real dumps ; and the provision of dummy armoured formations together with B echelon vehicles—comprising some 500 dummy tanks and 4,000 other dummy vehicles.

Results both from the actual fighting and from subsequent information received from enemy sources indicated the success of the deception plan. By minimising the scale of the forces visible in the northern sector, and by the use of this elaborate decoy scheme in the southern sector, it was possible to conceal the intention and timing of the northern break through, and to give the impression of an intended southerly thrust. When the offensive opened, the enemy was not in the best position to receive it. I need hardly remind you of Mr. Winston Churchill's words, when he told the House of Commons after the battle : ' A complete tactical surprise was achieved in the Western Desert by a marvellous system of camouflage.'

To sum up : we have seen that there exist certain well-defined scientific principles of camouflage—many of them derived from research in biology. As so often happens in any field of pure research, the fundamental work was done—without any thought of its ultimate usefulness—by men whose interests and scientific curiosity had led them, in the present instance, to examine and analyse the coloration and behaviour of animals in nature. When the war came, the principles had been well established, and were available for application by experts in many fields—the architects, engineers, display artists, model makers, photographers and others who played so important and vital a part in developing the art of deception for war purposes.

Unfortunately, at the beginning of the war (and in spite of lessons learned during the First World War), the possible methods, scope and usefulness of camouflage were by no means generally appreciated. Perhaps you will allow me to give a single example. When early in 1941 I took up my first service appointment, the Brigadier to whom I reported for duty welcomed me with these

words—he said : 'A camouflage officer is as much use to me as a refrigerator at the north pole.' It happened that we were no where near the north pole, but in tropical Africa, where a refrigerator would have been a very useful piece of equipment. However, I was not unduly discouraged by this somewhat chilly reception.

In the course of time, the indifferent attitude changed, until camouflage came to be widely recognised as a powerful potential weapon—a weapon not merely of defence, but of offence ; and one which was destined to play by no means a negligible part in the achievement of the high aim which, in those days, we all had in view : namely, the frustration and final defeat of the enemy.

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THE EDUCATION OF THE MAN OF SCIENCE

In view of the increasing part which science is expected to play in the development of civilisation and of the pressing need to increase the proportion of the population educated as scientists, the Council of the British Association gave an important place in the programme of the annual meeting in Dundee to a discussion on the education of the man of science. The following is a report of the discussion which took place on September 2, 1947.

Sir Henry Dale, O.M., G.B.E., F.R.S.

This discussion appears to me to be a very timely one. Among all the educational problems calling for debate and for solution at the present time, I doubt whether any could claim priority in importance over this one, of framing and providing the education calculated to produce men of science, fit to render the service which the world has a right to expect of them. It is a truism that Science will play a rapidly increasing part in providing the material framework of civilisation, and that the world will accordingly require a growing proportion of its population to be educated as scientists. That raises at once the problem of selecting those who are best fitted for such education and the related problem of framing and ensuring, for those so selected, an education which shall not only give them a training adequate for the technical demands of a profession, but fit them also to play their part as good citizens and acceptable members of a cultured community. If we fail to do this, then as the proportion of scientists in the world's total of learned men continues to grow, the general level of its culture and of its effective citizenship will fall. I take that to be a matter of agreement and a justification for this debate.

I venture to hope that we shall not give too great a predominance in our debate to the consideration of the education of men, who are to be scientists, in matters other than science. There was a time, not so many years ago, when our predecessors found it necessary to contend with vigour for the right of science to a place in any but a purely technical curriculum. It was grudgingly yielded, and I believe that among those exerting a powerful influence on educational thought and planning there are still some who regard the admission of science as a regrettable necessity, and as a mere concession to the need of the modern world for technical experts. I have even a suspicion that we men of science may sometimes in recent years have shown too tame a readiness to condone, or even by implication to adopt this cultural snobbery, by protesting almost too eagerly our determination to give the scientist a full opportunity for an understanding enjoyment of literature and the arts, while accepting it as a matter of course that others should regard a complete ignorance of science as compatible with a high culture.

I hope, then, that an adequate part of our discussion on the education of the man of science will be devoted to the way of teaching him science, not only as the essential training for his particular business in life, but as a central item for him, as, in my view, it should be for everybody else, of a really

wide and humane culture in this modern world.

One of the chief difficulties facing the educator must, I imagine, be that due to the embarrassing rate at which the total content of soundly established knowledge is expanding in almost every department of the natural sciences. Looking back at my own specialist field of animal physiology, as it was in my own student days, I should, on the vaguest of estimates, guess it to contain to-day at least five to ten times as much well grounded material of fact, required for a sound grasp of its present position and for a useful participation in its further progress, as half a century ago. In those days even a student could acquire an effective contact with the principal facts and the range of ideas proper to some four or five departments of natural science, and offer them all at what the first part of the Cambridge tripos examination regarded, then not so unreasonably, as an Honours standard. What is to be done about it now?

How are we going to produce astronomers, physicists, or chemists to-day, with an adequate grounding also in the facts and conceptions of biology, or graduates in biology or medicine, with an adequate working knowledge of astronomy, physics, or chemistry? And how can we continue to do this at the present rate of the expansion and replacement of knowledge in all these departments, without producing what Newton called 'little smatterers,' qualified rather for glib and pretentious talk over a wide range, than for serious participation in any special field of scientific enquiry? That, it seems to me, is bound to be a growing problem, an ever more serious dilemma for the educator in science as such. We cannot afford too close a specialisation. A wide-ranging grasp of the achievements of science as a whole is an important factor of its cultural value. Experience shows, indeed, how often important new growing points of science appear where fields of enquiry, which once seemed widely disparate, come newly into contact and establish a margin of common interest, as is happening at present with physics and biology. On the other hand, I believe that a case could be made for the proposition that science can make its greatest contribution to a man's real education, to his intellectual and moral discipline, by awakening him to the ideal of an exact and comprehensive knowledge, a competent and critical grasp of the whole order of facts and ideas belonging to one sufficient but limited range of scientific enquiry. How, under present and still developing conditions, can we devise a scientific education which is at once wide enough and, at the same time, intense enough at the chosen point, to produce men of science who are savants without being pedants?

Others will deal, with much greater experience than mine, with the need of the scientist for education beyond the range of the natural sciences and the danger of early specialisation. I am certainly no advocate of early specialisation, provided that the alternative gives something better than an unsubstantial veneer. I suppose that one of the accusations most frequently levelled at the education of scientists as a whole, and too often I fear with justice, is that it does not teach them to express their ideas effectively, or to present the results of their investigations clearly and vividly, without verbose ambiguities, or wearisomely reiterated clichés. But while we admit that there may be real ground of complaint and criticism on this account, I think that we must show a scientific caution about the diagnosis of its cause and the prescription of a remedy. Certainly the scientist, like everybody else, needs to read sufficiently widely and wisely to enrich his vocabulary and to acquire an adequate ease and skill in the use of his own language; and it may well be that he is specially prone to attempt to express himself in a limited, technical jargon. I think, however, that before we put too exclusive a faith in extra-scientific studies as a cure for these tendencies, we ought to consider whether the fault may not lie mainly in the teaching of science itself. It may be doubted whether the power to give clear and simple expression to a result, or a conception, is not an essential factor of clear thinking about it. I am not sure that it should not be more clearly recognised as a duty of the teacher of science to train his pupils, by precept, example and practice, in the clear, simple and vivid expression of what scientific knowledge they possess. If I may be permitted to speak from personal experience, I am conscious myself of having gained more than from any other item in my school training, from the insistence of a science teacher, who resolutely refused to accept an answer until it was simply expressed, in language which the most ingenious perversity could not misunderstand.

The history of Science can show plenty of examples of men who had, at best, no conspicuous advantages of literary education, whose writings on science were, none the less, admirable as literature. Let Michael Faraday and T. H. Huxley stand for examples; of whom the latter may be cited as authority for the view that the first requisite for a good literary style is to have something new and important to say, and the second, to be able to say it with simple brevity. I would not be misunderstood as underrating the cultural advantages of as wide a knowledge of literature and the arts as the student can acquire; but the time for formal education is limited and its essential content continually expanding.

I believe, then, that our first duty, in relation to the subject of this discussion, is to make the teaching of science itself cultural. And I have yet to meet the man of science who is proud to be ignorant of literature and the arts, though there are many literary men and artists who make their ignorance of the rudiments of science a matter of open boasting.

Dr. Eric James

We are faced to-day with a most pressing educational problem. The importance of the scientist in the community is being very generally recognised: the number of scientists entering the service of the state, of industry and of academic life is very rapidly increasing. By what means can we ensure that these scientists shall in the future really be capable of fulfilling their increased obligations? That question lays a heavy responsibility on those of us whose duty it is to educate them, and it is a recognition of that responsibility that brings us here. My own function is to say something about the provision of an adequate education for the scientist from the point of view of the schoolmaster.

Our approach to scientific education in the schools must be a threefold one; it is to produce potential scientists of high quality as regards their specialist knowledge; to see as far as we can that they are aware of the social relevance of the scientific discovery, and thirdly to try to ensure that they are people with a full general education, using the word in its very widest sense.

As regards the first of these duties, the maintenance of high specialist standards, I will say little. Indeed, one would have thought it unnecessary to say anything, but there are tendencies of various kinds which may depress the standards of grammar school work so much, if they are unchecked, that we shall be unable to maintain the quality of our university entrants. I would remind those here from the universities how dependent they are upon those standards.

There is a deplorable tendency for some university teachers, usually those at the greatest distance from the first year students, to say 'we do not mind if they do not know any physics; *we* will teach them that.' Such statements are unfortunate not only because they are inconsistent with what the universities actually require, but also because they lend support to those who seek to lower the academic standards of our schools by schemes of multilateral organisation or by proposals to abolish external examinations. There is also a tendency for a high standard in science to be regarded as the enemy of general culture and for higher certificates and, still more, university scholarships, to be regarded as hampering genuine education. In my view this is altogether misguided. There are, no doubt, a number of faults in these higher examinations, but on the whole I believe their influence to be healthy and stimulating. In general I would say that as regards the specialist education of the scientist we have made good progress. The serious teaching of science in schools is of comparatively recent date, but it has shown great capacity for growth. There is much room for experiment and change, but the Science Masters Association has machinery for encouraging such change and for consultation with the universities, and provided that we can keep up the general standard of grammar school work we shall improve still further.

Greater controversy centres round our other tasks. How are we to train science specialists who shall be more than specialists and who shall be sensitive to the social responsibility they carry, or prepared by the breadth of their perceptions to undertake the highest administrative responsibility? Here again I do not feel that we have been as unsuccessful as is sometimes supposed. The complaint that scientists are uncultured rests too often on a narrow view of culture. Nevertheless there is a certain truth in the criticism of some of our science students; certainly there is no room for complacency. What is the solution?

In my opinion, some of the remedies proposed are worse than the disease. There is a tendency to assume that a general education for scientists can be obtained simply by devoting a certain proportion of the timetable to non-specialist studies; that it does not matter a great deal what is taught, as long as it is not science. Nothing, I believe, can be further from the truth. The character of a scientist's general education will depend far more on *what* the outside subjects are, and how they are taught than on their number. This is the error in the suggestion of a four-subject Higher Certificate, one principal subject being unconnected with the pupil's specialism. Such a course would canalise the pupil's non-scientific interests along one line, probably a foreign language. It would end the genuinely broad non-specialist teaching that now goes on in many schools. The general culture of a scientist is not automatically broadened by five periods of compulsory French, and the view that it is may do much harm to higher education.

I do not believe that we are yet in a position to be dogmatic over the content of non-specialist courses: they should certainly contain some English, some religious instruction and probably some history. We can, however, say with certainty that they must be taught with the greatest freedom by men who are genuinely interested in the

problem. It is disastrous if the general education of scientists is handed over to some unwilling teacher who imagines that his task is to smear a little culture over a group of barbarians. The aim must be that these boys shall meet in their last year or two at school some of the problems of life and society in such a way that they will want to think and argue and read about them for themselves. One teacher may approach this object through the direct means of current affairs, another indirectly through elementary philosophy, and I believe that no one who has read with a science sixth form some of the simpler dialogues of Plato will ever regard a modern language as a satisfactory alternative. But, it may be objected, although some schools may do all this and indeed have done it for years, it will not touch a number of schools which will continue in unbridled over-specialisation. What sanctions can we employ to ensure that scientists at all schools do receive some general education? If a sanction is required I believe it may be found, at any rate as a temporary expedient, in a general paper in the Higher School Certificate. The kind of general paper set in Oxford and Cambridge scholarships with its very wide choice of questions seems to me far better than its critics allow. It has suffered from one fatal defect: the suspicion that it was not taken seriously. If that suspicion were removed and if a similar paper were compulsory in all Higher School Certificates I believe the right kind of general education would be stimulated in our science sixth forms.

But the remedy ultimately lies deeper. We complain that our science students lack general education. But do we really know what constitutes a general education in terms of the social and cultural and spiritual needs of our time? I would like to see a really serious attempt made by the universities and the schools to answer that quite fundamental question. Until we are more precise in our approach to it then much of our discussion on this and kindred topics must be vague and undecisive.

There is a further point of view of great importance that I must raise at this point. An improved general education for the scientist must be accompanied by a similar improvement in that of the non-scientist. The classic, the historian and the modern linguist should not leave our schools without some knowledge of the social effects of scientific discovery nor in ignorance of the delevopment of scientific thought. There are, of course, some schools where such sixth form work is already done. I would urge not only that much more progress should be made in this direction, but that the courses should be followed by scientist and non-scientist alike, for I believe they would do much to place scientific studies in their appropriate social context for the scientist himself.

It is strictly no part of my duty to say anything about the universities, yet I am emboldened to say two things which seem to me relevant by the fact that after all we in the schools do rely on the products of the universities: the training of scientists in the schools can only be satisfactory if the university graduates who teach there are adequate in quality and supply. The first point I would make is to deplore the tendency to regard the scientist as more broadly educated and certainly more fitted for teaching if he has done two or three science subjects at the university than if he has specialised in one. In fact the man who has gone deeply into a single subject, who has perhaps obtained some vision of it as a growing body of knowledge by doing some small piece of research, one of the most profoundly educational experiences one can have, will usually be a better teacher not only of that subject but of others. It may be a paradox but I believe it to be true that the more specialised the university course within science itself, the more likely is the student to be a broadly educated man. A course in which two or three sciences have to be brought to degree levels leaves a man far too little leisure to seek genuine self education through literature or philosophy or wherever his taste may lie.

The second point is this. We are wasting our time in discussing the education of scientists if sufficient science teachers are not forthcoming. To a great extent the shortage is, of course, due to financial reasons. But there are other factors, and one of them is the attitude all too common in university laboratories, that may be summarised in the remark heard by all of us, no doubt made by some, 'My good fellow, you're too good for teaching; you must stay in research!' That attitude is a danger to the whole future of scientific education.

I believe, then, that our problems can be solved essentially by closer co-operation between the schools and the universities. That co-operation exists already, but it must be stimulated in every way. I would like to see more professors actually visiting our schools, and finding out exactly what goes on there. We must realise that many of our problems are common problems; that without a high standard in the grammar schools the universities cannot flourish; that only a sound university system can supply the inspired teachers that we need in our schools; and above all that only by consultation and discussion shall we arrive at a clearer view of the nature of that common basis of culture without which science itself must be frustrated.

Sir Lawrence Bragg, O.B.E., F.R.S.

THE plan of the science courses is not the same in all universities. In some, a course in which several branches of science are given equal weight is a preliminary to a specialised Honours course. In others, a student enters a definite Honours school when he begins his undergraduate career. Conditions of entry also differ. But certain broad generalisations can be made which represent fairly enough the typical university course in science. A man enters with Higher School Certificate qualifications, and specialises in science alone at the university. Chemistry, physics and mathematics, or zoology, botany and chemistry, are the most common groups on the A and B sides respectively, one subject being studied intensively and the others being regarded as subsidiary. Three years is the usual undergraduate course, though a four-year course is not uncommon and in certain cases is required.

For the man who is adopting science as a profession, a further three years is now the almost universal practice. These years are spent in research and lead to the Ph.D. degree. They are also used for postgraduate courses of study ; the specialised courses for which no time can be found in the three years' course for the Honours degree are well adapted to Ph.D. students.

It must thus be recognised that the normal course of training for a man who is going to base his professional career on his scientific ability is a full six year course, in most cases all taken at one university. We fall into line with the general practice of continental universities, where about six years is regarded as the necessary course for a full university qualification. It is true that we give a degree after three years, and that a large proportion of our students drop their university studies at this stage, but they are for the most part going into business, civil service, teaching or some other career where an advanced and specialised knowledge of some branch of science is not required.

Another point about the university training is worth making. University teachers are fortunate in that they both train and test their students, so that they can plan their courses in the way they consider best for the students' future careers, and are not obliged to prepare them for a test set by an external body. The university course therefore has great flexibility. Further, a science course can be made a very closely integrated whole because of the intimate contact between teachers who are working in the same laboratory. This daily contact has a very important effect in ensuring that courses do not overlap, and that essential parts of the subject are not missed from the lectures and practical work. The fact that the teachers are working in the same building is much more effective in securing this end than can be any series of meetings round the committee table to plan courses. The advantage of the laboratory as a social unit is, in my opinion, not always fully realised.

The object of the course should be to train the student in certain fundamental mental disciplines which can only be learned by several years of study and practical work. To take physics as an example, there are several fundamental ways of thought which have to be acquired by concentrated effort on the student's part, and patient illustration by examples on the teacher's part. I would cite the following :—Thermodynamics and statistical mechanics, classical electricity and magnetism, physical optics and wave propagation, electron theory and the theory of the magnetic state, quantum theory and atomic structure, properties of matter as dependent on atomic arrangement, nuclear physics, relativity. Ability to follow mathematical analysis binds the whole together.

' Education is what remains when one has forgotten what one has learnt ' is a saying attributed to Ellen Key. An Honours student, a few years later, would be quite unable to answer more than a small fraction of the questions he coped with successfully in his finals, but something more important is retained. Confronted by a problem, he falls back again into the old lines of thought and uses the conception he has acquired, just as when a foreign language has once been learnt, it always comes back with a little practice when one has occasion to speak it again.

There are in addition certain general acquirements which we try to give to our students :—How to design an experiment, how to consult literature, how to write a paper. The last two cannot find a place in undergraduate training, they must wait for the postgraduate years. But at all stages we can try to instil scientific curiosity, the driving force for all scientific work.

What is the value of this course ? That it has been successful in producing leaders in pure science which have kept our country well in the forefront of world science is generally accepted. We must not throw away this advantage, and this raises an important point. There is much talk nowadays of greatly increasing the size of our universities, and often the implications of such a change are not realised. Our present university courses are based on the assumption that the leaders of scientific thought, who are and always will be a small band, are brought into intimate personal contact with the student in the undergraduate years from 18 to 21. If

the undergraduate numbers are to be greatly increased, the whole plan must be altered. The contact between student and leader will have to be restricted to the postgraduate years, and the undergraduate teaching become advanced school teaching under the direction of a faculty dean who is virtually a headmaster, as we see happening in the United States. There is no half-way house. We are, in fact, already beginning to suffer in an attempt to teach larger classes while still retaining the former university framework, and losing the advantage of either plan. The leaders of thought, who are still supposed to take an active part in all decisions affecting the undergraduates, are finding themselves so burdened with administrative decisions that they have no time for original work. This is definitely a case where we cannot have our cake and eat it ; we cannot increase the number of undergraduates and still give to them the same kind of university education which was formerly possible for a smaller and more select student body. While Honours classes were about a dozen strong, the men were known individually to the Professor and his senior staff. When numbers rise to fifty or a hundred, as they are now doing in many universities, this personal contact is completely lost. If we think that the contact ought to be retained in the undergraduate years in accord with our former university tradition, we shall have to provide the larger numbers of scientists needed by the country by some other type of college, not by diluting our university courses.

I believe that our present courses also provide the right training for applied science in its higher forms. Our industrial friends are sometimes critical of our university product, but I do not think the science teaching is to blame. The success with which university-trained scientists tackled practical problems in the war shows how flexible their education had been. The criticisms are more fairly levelled at certain other aspects of the students' education which are mentioned below.

What are the faults of the present system ? The most serious criticism we have to face is that a scientist has a narrow and specialised education. This applies not only to his university years, but also to the years from fourteen or fifteen onwards when he begins to specialise in the secondary school, and even further back to the years of fierce competition for a place in the secondary school.

When an industrialist criticises a university course because it has not given the student some particular bit of knowledge affecting the processes in which that industrialist is interested, I will argue the point with him. We appreciate, much more than he does, how brief are the years of training, and we think we are better judges than he is of how to adjust the claims of different branches of science to that time. But when he says that he finds our men impatient and intolerant, difficult to fit in with others, and lacking in knowledge of the world, we must consider his criticisms very seriously. Even more fundamental is the criticism that our scientific training leaves the man without the appreciation of a whole series of values which cannot be defined scientifically. His segregation has been so effective that he talks a different language, and cannot play his part in the world of affairs, because he cannot understand or make himself understood by men who have not had a scientific training like his own.

What is the cause of this specialisation and how can its evil effects be avoided? The interesting thing is that everyone, scientists most of all, agree that it exists and that it is bad. If specialisation were forced on the student because university teachers insisted on it as necessary in order that a sufficiently high standard might be attained, we could hope to cure it by convincing the very small minority who hold such views of their error. But the problem is much more complex. In recent years, we held a meeting at Cambridge between representatives of the university scholarship awarding bodies and school science masters and mistresses to discuss this question of specialisation. There was unanimous agreement that a general education in which arts and science were equally balanced was both the best thing for the pupils and the desirable foundation for a subsequent science course at the university. The difficulties arose when we discussed how we could attain this ideal. The present system of scholarships and admission tests is forcing us, against our will, into intense specialisation.

Now there must, in any educational system, be a series of barriers which only let past those students who are able to profit by a higher stage and should go on to it. But I feel sometimes that no alteration of the nature of scholarship or admission tests will by itself ever cure specialisation. The brighter young people will always be trained like race-horses to make the best show they can for a test set by an outside body. The cure must be a much more drastic one ; the deplorable over-strain of young brains owing to the fierce competition will always take place as long as the test for admission to a further stage is applied by the educational institution to which the applicant seeks admission, and not by the educational institution which has been training him and knows him well. The university decides which of its students are worthy of a degree and which are worthy to pass on to the higher postgraduate years. Why

should not the preparatory school decide which of its pupils are fit to go on to a secondary school, and the secondary school which are fit to go on to a university? I realise all the difficulties, but to say that it could not be made to work is equivalent to saying that school teachers are not as responsible and fair as university teachers, and I see no reason for thinking that there is such a difference. If the pressure could be relieved, our young people would have more chance to get to know the world and be better all-round human beings.

This is too big a question to enlarge upon here, however, and I will confine myself to what might be done at the university. One is inevitably forced to adopt a policy of gradualism in any educational change. A proposal which has been put up at Cambridge, as an instance, is that there should be a course in the philosophy, history and economics of science for our undergraduates and that it should be given by our arts colleagues. I think that the latter part of the proposal is more important than the exact content of the course. Our scientists would be admitted to a different world. The immense popularity of a course of English for scientists which is now held in the Long Vacation has been most illuminating as showing how much the undergraduates feel what they are missing by getting no contact with the arts side.

Nothing will be gained if arts and science, or school and university, attack each other and lay the blame on the opposite party for what all regard as an evil to be cured. A new problem has arisen because of the growing importance of science, which has not yet found its proper place and relationship in our education and life, and we must make a joint attack on the problem.

Sir James C. Irvine, C.B.E., F.R.S.

I AM inclined to divide the problem embodied in the title of this discussion into two interrelated parts, namely training for scientific work and education for scientific life and, more important, for life generally. That there is such a distinction is perhaps not fully realised except by teachers, but I am conscious of it through reflection on the limitations imposed on the rank and file of scientists—by deficiencies, not so much in the training they underwent, as in their education. In my own successive capacities as a teacher, professor, director of a research school and now as one who continues to take a personal interest and pride in young scientists, I have come to the mournful conclusion that I have trained many scientists but educated few.

It is small wonder that the problem of how the scientist should be educated has been often in my mind, and that I count it a privilege to have exchanged opinions on the subject with men such as Henry Armstrong, something of a rebel, Rutherford, regenerate in every respect, Jones, a master of exposition, and the distinguished father of the distinguished speaker who preceded me, Sir William Bragg. The training of the scientist must vary according to the particular field of science to be cultivated, but we have long passed the stage where it was possible to discriminate sharply between the physical or exact sciences and the biological or so-called descriptive sciences. At one time the prescription was simple, mathematics for the first, top training in observation for the second. But physics, chemistry and mathematics have now invaded biological science to such an extent that all scientists, irrespective of their field of specialisation, must have a working acquaintance with the three fundamental subjects I have mentioned. Equally I believe it to be of the utmost importance that the physical scientist should be introduced to the study of living things, even if only on an elementary level, else he will look at nature with but one eye and be excluded from taking an intelligent interest in many developments of major importance.

If we accept these principles, the university course of the young scientist begins to take shape. He must study not one science but several, and combine this particular training with the highest possible standard of specialisation in his chosen subject. This will require at least four years, leading to graduation with honours. I do not see how it can be done adequately in three, and I prefer four. I do not favour the general honours science degree course, agreeing fully with Sir Henry Dale that the rapid growth and ramifications of the individual sciences demand that specialisation must necessarily be restricted within a narrow field. Inquiry should be deep rather than broad. This may appear to be regrettable, but circumstances force us to this policy. I was delighted to hear the High Master of Manchester Grammar School say that he has not found specialisation a handicap to successful teaching in the schools. There is no reason for any such divorce. Specialisation and stimulating effective teaching can and indeed must go together. Admittedly the training of the scientist, no matter how efficient he may be in his special subject, must of necessity be incomplete when he takes his first degree.

I am grateful to Sir Lawrence Bragg for pointing out emphatically the valuable use which can be made of the three subsequent years now generally spent in postgraduate research. But note, too frequently these years are devoted solely to the investigation

of a single narrow problem leading to a thesis qualifying for a higher degree. It is my belief that these years can best be spent in providing a research apprenticeship supplemented by the rounding off of the education of the young scientist. Probably for the first time in his life he will meet his professor personally as man to man, not as master and pupil, at the working bench. There he will derive experience and encouragement ; there he will receive advice ; together as partners they will face and solve their difficulties. Let this young man or young woman in these three postgraduate years receive a severe drilling in research, by all means let him have his doctorate and a public paper or two for his encouragement, but use the time also to fill in the educational gaps. He should be encouraged to attend further courses of instruction in his own and other subjects. He must be trained to recognise and to define scientific problems, to devise methods for their solution, to develop his critical judgment in interpreting his own results. He must be trained by diligent practice to acquire the art of writing scientific papers and reports. I believe this to be the most important stage of the scientist's education.

I believe that, if the research supervisor interprets his duties aright, the young research worker will likewise acquire at the working bench the character-forming factors which are necessary when the man of science becomes a man of the world. Obviously I have prescribed a high standard for the research supervisor and sketched for him a laborious self-sacrificing life, for the more he does for his young disciples the less time will he be able to devote to his own problems at his own bench.

All that I have said regarding both undergraduate and postgraduate training involves as a first necessity that the scientist should at some stage and in some way have passed through a thorough discipline in the use of the English language. This is not an example of intellectual snobbery. It matters little in what way the young scientist acquires this discipline, but he must certainly acquire the facility to write and to speak in clear precise terms, coupled if possible with a scholarly selection of words. The flexible use of exact English is best obtained, I believe, in addition to diligent reading and study of English itself, by the study of another language. I am old-fashioned and believe in the special value of Latin. If you disagree, I commend to you as an alternative the method employed by Benjamin Franklin to convert the slovenly language of the printer's boy into the eloquence of the master scientist.

It is my opinion also that the budding scientist should be given a drilling in formal logic as part of his intellectual equipment. But I am by no means convinced of the necessity for a training in philosophy in the wider sense. The boundaries between philosophy and the sciences proper are in process of being dissolved, but the frontier zone is best covered by collaboration rather than by individual effort.

All that I have recommended will succeed or fail according to the preparation received at school by pupils aspiring to the scientific life. What the universities get from the schools determines the kind of scientist the universities give to the world. In this connection the evidence brought forward by Sir Lawrence Bragg is important. School courses should include a reasonable balance between what we may call arts and science subjects, even if this involves some sacrifice or diminution in scientific specialisation. There is no ground for divorce between science and culture, and if the teacher of science sees to it that his science pupils make full use of the training they have received in non-scientific subjects there will be less complaint from the lay world that, although the scientist has something to say he cannot say it. My views are shared by the headmasters of the principal schools in this area. It may interest Mr. James to know that the University of St. Andrews has already adopted the suggestion he put forward, and we now hold regular week-end conferences twice a year with representatives of the schools on our university problems. These gatherings have been of the happiest nature and to our mutual advantage. One of the great problems of discussion has been the very one we are discussing now, the education of the scientist.

To sum up my personal views, if a boy has been trained at school on the lines I suggest he can safely be launched directly on a four years' course in science at the university, followed by three years of postgraduate study and research. Under teachers who are themselves cultured, he will get all the culture necessary from his scientific studies, and thereafter he will pass to the outer world as a teacher in school or college, as a research worker in industry, as an administrator, armed with an equipment which we may claim to carry both training and education. So long as he remembers, as we all must, that training is never complete and education never finished, he will be able to take his place as a useful member of society capable of upholding the dignity of science and of serving science, and with that, serving his fellow men.

Sir Arthur Fleming

The qualities about which I am to speak are inherent. They may be developed to

some extent during the period of formal education, but mostly they are not discernible until the science graduate has found employment. The field for employment of science graduates is increasing year by year, and comprises, for example, teaching, medicine, agriculture, transport, mining and every branch of the manufacturing industries. Clearly the technical requirements in the different fields will vary enormously, but in my experience the non-technical qualities are the same for all jobs, although they may not apply to the same degree in each job. With this in mind I shall confine my remarks principally to engineering manufacture since this is the basis of all manufacturing industry.

It is within the memory of some of us present that in the early part of this century the science graduate had rather a grim time in getting a footing in a manufacturing firm. It was the day of the so-called practical man, usually one of great calibre, who had fought his way up from the rank and file by sheer force of ability and personality, grasping such technical knowledge as could be acquired by the sparse part-time facilities then available, and one who looked back along the path of his own career, and was quite certain that this was the only way in which the successful engineer could be trained.

By degrees a few science graduates percolated into industry, but always on account of their technical qualifications, since these were beginning to be necessary for design purposes. Later the science graduate entered the commercial field as technical products were then being bought by technically trained engineers.

The next stronghold was that of the production departments, and here there is still a good deal of opposition to the science graduate, although in progressive industry such men are being absorbed in increasing numbers.

It was, however, the development, twenty-five years ago, of research in industry which opened the way for the employment of large numbers of science graduates first in research, and then increasingly into the various industrial fields, such as design, selling, production and research.

All jobs call for same preliminary training. In some cases this has been acquired by the graduate accepting a position and then picking up the experience necessary for him to fill the job successfully, but more and more is it becoming recognised that the science-graduate is simply raw material, possessing, it is true, a fundamental background of scientific knowledge, but needing formal training in various phases of manufacture before being posted to a specific appointment.

Leading manufacturing concerns in many industries have recognised schemes of training usually of two or more years' duration, but these training facilities are not, as is generally supposed, solely for the purpose of imparting knowledge of engineering, but serve rather as a means of presenting a many-sided picture of all the possibilities in engineering with contacts which enable the trainee to find himself. He becomes attracted to one or other of the principal fields, such as those I have indicated, and then his real training commences.

It might be noted that generally he is selected before his academic qualities have been assessed by the University examinations, and skilled selectors will judge the man's innate capabilities as revealed by interview and discussion as well as academic ability.

A review made recently of over a thousand science graduates who had passed through the training scheme of a large engineering organisation showed that by about the age of 35, say ten years after graduation, 50 per cent. had ceased to use their science background as their main stock-in-trade, while at about 40 years the percentage had risen to 75 per cent. That is to say these men had developed innate qualities which had become of greater value in their careers than their science training, although this latter would always be of immense importance, especially in so far as it had developed the habit of the scientific approach to all problems.

Assuming the need for such characteristics as honesty and good health, qualities which are important but which do not fall with equal incidence on every type of job include leadership. This is particularly essential in the case of the trainee who takes to the production side of the business. He must gain the confidence and esteem of the workers and must be an inspiration to them. Again the ability to form sound judgments is important in every field. In research it is necessary for the science graduate to appreciate his position relative to that of everyone else in the organisation, and to be tolerant towards those who have had lesser opportunities for advanced education. The graduate is apt to have an overweening sense of the importance of his particular contribution in, say, the development of a new tool, material or product, and to forget that his work is useless without the assistance of the highly skilled tool-maker, the artisan, the labourer in the shops, the draughtsman, and the designer, and he completely overlooks the fact that a management has to use its best judgment in deciding whether to risk money in developing a project that has been conceived. Initiative and enthusiasm are, of course, of primary importance, and persistence in carrying to a finish whatever has been started is vital.

The fact that the science graduate may not depend ultimately on his scientific knowledge increases the importance of the development of the cultural side of his education, and this should be such as to enable him never to be at a disadvantage in his social associations with the leaders of any other profession.

It is not always realised that not all men of science come from the Universities. Some fight their way upwards, with all the handicaps of a limited general education, by part-time study. Such men are usually of fine calibre, and possess to a marked degree the non-technical qualities which make for success, especially in the way of grit and determination.

Striking results have been noticed with certain selected men who have had the opportunity of pursuing for one term only a course of cultural study in Cheshunt College, Cambridge. Men have come back from such courses inspired to climb upwards and extend both their general and technical education to the utmost of their capacity.

In our personnel we have our greatest asset, important at all times, but vital at this time of national crisis. It is of the greatest importance that those non-technical qualifications that are so significant as the basis of a successful career should be developed to the utmost and dedicated to service.

Sir John Lennard-Jones, K.B.E., F.R.S.

Timeliness of the Discussion.

Largely as a result of the war the status of the scientist has been raised in the national life. He is regarded as a potentially important contributor to its economic strength and an interested party in its social problems. There has been an increased recognition of the possibilities of science and the powers of the trained scientist. This is reflected in the growing interest of contemporary literature in scientific affairs. The opinion of the scientist is often sought on major matters of state and this must induce a sense of responsibility and concern that the right advice is given. The searchlight which is being focused on the scientist will necessarily expose his limitations as well as his powers.

It is fitting that at such a time scientists should subject themselves to a searching inquiry of their training and qualifications. No place could be more appropriate as a focus for such a discussion than a meeting of the British Association where all branches of science are represented and where so many sections of the scientific community are assembled.

Definition of the Man of Science.

We have not, during the discussion, defined precisely what we mean by a Man of Science. To some it connotes that small but highly distinguished band of investigators who lead in the paths of discovery. To others it means that large body of scientific craftsmen, who, having had a university training in science, have entered industry, the civil service, the teaching profession or any other similar walk of life. We have to distinguish clearly between the needs of the specialist and the needs of the average scientific worker. As Sir Lawrence Bragg has said, the methods now in use at our schools and universities have in the past created scientific leaders of the first magnitude and we must not lightly discard the virtues of such a system. On the other hand, it may well be argued that the courses at universities are designed primarily for the production of the specialists and are not necessarily well suited to the needs of those of more average ability.

My experience has been that scientists of the very first rank are usually men of wide interests and cultural attainments. Nothing could be more specialised than the courses for mathematicians, certainly at Cambridge, and yet the ablest mathematicians are often men of great literary ability. I need only mention Sir Arthur Eddington and Sir James Jeans, both recent products of a mathematical school, who have attained distinction in the world of letters.

It is of interest to enquire why it is that the scientist of the most gifted kind is also a man of culture. First, he has ability and powers of mind of an unusually high order. Next he has wide and intense interests. It may be that these are associated with or arise from his predominant life's work, but all life, all nature arouses his intense curiosity. Finally, being of outstanding ability, the greatest scientists contrive also to have leisure. These three qualities, ability, interest, leisure, lead to a fund of general knowledge and culture which we describe as education. Perhaps the greatest of these is *interest*.

It is not of these unusually gifted men that we are speaking to-day. Implicit throughout the discussion has been the assumption that it is the good, competent but not exceptionally brilliant scientist with whom we are concerned. For our purpose we may define a man of science as one who is professionally engaged in the pursuit of science, whether it be in teaching or in research or in the application of science to industry.

What is Education ?

Education is a more difficult term to define. It is easier to say what it is not. It is not simply the acquisition of knowledge, the filling of the mind with facts, or even familiarity with a particular culture. As has been said by Sir Lawrence Bragg, education is what

remains after that which has been learned has been forgotten. It may be more the method by which knowledge was acquired, the habits of thought and concentration engendered by study, or that discipline of mind produced by long and severe mental application. Or again it may be the cultivation of personal aptitudes and abilities to enable a man to live a useful and satisfying life. I liked the description given by Sir Henry Dale in his opening remarks. Education should provide not only a training adequate for the technical needs of the man of science in his profession, but should fit him also for his part as a good citizen and an acceptable member of a cultured community.

The President also stressed the importance of the power of communicating thought and the discipline of accurate and lucid exposition. In this respect there is a scholarship in science as in the tradition arts. This was reinforced by Sir James Irvine who favoured the study of language, preferably Latin, to assist in the art of writing and speaking the English language. We can surely all of us agree that a reasonable competence in the art of self-expression, both of an oral and written kind, should be regarded as a necessary qualification of a man of science.

Sir Arthur Fleming, however, indicated other traits of mind and character which are necessary for success in the active and developing fields of scientific endeavour. He mentioned qualities of sound judgment and a capacity for leadership. How can these desirable characteristics be developed in the course of education? To some extent they are probably innate and can only be fostered and developed by training. Judgment involves experience and the capacity to profit by experience. Leadership involves not only courage and judgment but also self-confidence. These qualities are not likely to be engendered by study but more by contact with affairs and association with one's fellows.

Education must accordingly provide for social contacts on an adequate scale. Schools and universities cater in different degrees and with differing success for these requirements. There is a widespread feeling that further facilities for residence in the universities are a necessary development to meet this need.

There are two competing qualities which have to be reconciled. Schools and universities are based on a severe selective competition and this begets a pronounced *individualism*. On the other hand success in after-life depends on a capacity for *co-operation*, particularly in a society where planning is the accepted motto.

The education of the scientist must be such that it gives him points of contact and common interest with his fellow men and at the same time permits him to reach forward to the limits of knowledge of his own field. In this sense it must provide ever widening expansion in the horizontal plane, the plane of general experience, and at the same time provide the path to the heights of specialist knowledge

The Need for a New Approach.

We have been dealing with the ideal of an educated man of science. Once we are agreed on the general objectives, the means will not be lacking to attain them. Dr. Eric James has dealt with the problem from the point of the schools. He has pointed out and deplored the tendency to assume that a general education can be obtained simply by a suitable arrangement of the school timetable. He is surely on the right lines when he says that the aim should be to introduce to boys at school some of the problems of life and society in such a way that they will want to read and think and argue for themselves. In other words he is anxious to promote their interest in the wide field of knowledge by using as a central nucleus the scientific knowledge they already possess. Could not history—and in some cases literature—be taught from this new angle? Social history is as fascinating to the scientist as to the historian. It provides contacts with daily life and experience and to the scientist is of more impelling interest than the study of political history. As for the acquisition of literary prowess and style, Sir Henry Dale has told us in his opening remarks that he first obtained his training from a science teacher who imposed high standards of accurate composition.

General Conclusion.

The discussion has drawn attention to an important problem. It has raised more questions than it has answered. These are the concern of the school teachers, university teachers and industrial scientists alike. There is need for a closer study of these and for close consultation between all the principal parties concerned. This conference will have achieved its aim if it stimulates further discussion and leads to the setting up of competent, representative bodies to study the problems involved. Thus may we hope to advance along the road of educational progress for the benefit of the next generation of men of science.

OPERATIONAL RESEARCH IN WAR AND PEACE

MUCH of importance was achieved by ' operational research ' teams during the war and the opportunity was taken at the meeting of the British Association in Dundee to consider the techniques developed during the war, and the possibility of using them in peace. The following is a summary report on a discussion arranged by the Division for Social and International Relations of Science, over which Dr. C. H. Desch, F.R.S., presided, on August 30, 1947.

Sir Robert Watson-Watt, C.B., F.R.S.

OPENING the discussion, Sir Robert Watson-Watt said that in some measure he shared with Mr. A. P. Rowe responsibility for the conversion into an orderly, organised system of the sporadic, unordered and scarcely recognised activities that might before 1937 have become Operational Research by being clearly differentiated.

Operational research was broadly visualised as the application of the basic scientific methods of measurement, classification, comparison and correlation to the selection of means for attaining, with the least expenditure in effort and in time, the maximum operational effect which could be extracted from the available or potentially available resources in personnel and material. The operational researcher was visualised as requiring dual ranges of knowledge ; on the one hand a wide and fairly detailed knowledge of the technical possibilities and limitations of the equipment in use or capable of development ; on the other hand a close personal knowledge of the working conditions in which it was to be used and of the people who were to use it. The operational researcher must be equally at home, and equally welcome, in the development laboratory, in the squadron mess, on the tarmac with the aircraftsman, and in the staff conference. He should be constantly in pursuit of numerical values, however rough the approximations, he should be trying constantly to isolate the consequences of the planned variation in one of the determining factors from all other variations in the ensemble under study.

If terms of reference must be given, they might be ' to examine quantitatively whether the user organisation is getting from the operation of its equipment the best attainable contribution to its overall objective, what are the predominant factors governing the results attained, what changes in equipment or method can be reasonably expected to improve these results at a minimal cost in effort and in time, and the degree to which variations in the tactical objectives are likely to contribute to a more economical and timely attainment of the overall strategic objective.' And these terms of reference were offered for operational research in industry as well as for operational research in war. He believed operational research to be an important contribution to the still unsolved problem of the relation between the administrator and the victim of that opprobrious epithet ' the expert '.

The practice of operational research in the three services differed notably in character; the pioneer practice in the R.A.F. might almost be described as centrifugal, certainly as highly devolutionary ; the Naval counterpart was by contrast relatively highly centralised. Both applications of the basic conception were vital, but scientific advice at high policy levels was liable to be ill-balanced if it were not based on direct scientific interpretation, in the field, of the experience of the everyday user in the field.

Referring to Sir Henry Dale's Presidential Address the speaker said that the President had a right to ask whether ' we can accept as directly obvious the suggestion that operational research . . . would qualify for guidance in the immeasurably more complicated and fundamentally different problems of reconstruction in peace,' but it would be disastrous if this legitimate query were misread and misapplied as a positive statement of rejection.

Since the essence of operational research was the informed unravelling of the variables in a not immeasurably but excessively complex ensemble, it could not be supposed that we dare lightly reject it in application to a still more complex ensemble—and indeed it might be doubted whether the peace ensemble was in fact more complex than the war ensemble. It was surely some simplification that while the conflict in war was a conflict of aims, the conflicts of peace were merely conflicts of method.

It would be either naive or disingenuous to pretend that discussion on the application of operational research in peace-time industry was separable from discussion on the mobilisation of science in peace to consolidate that saving of civilisation to which the mobilisation of science in war was an indispensable contribution. The President had referred to ' conscription of science ', ' surrender to

authority', and 'totalitarian use of science' in his Address, but Sir Robert Watson-Watt said he knew of no proposal that scientific workers should surrender to any authority other than a council of their peers.

'There is no one of us in the community of science who is unaware that the capital of our intellectual state, the holy place of our scientific consciences, the Parthenon of our æsthetic fulfilment in science, is the Walled City of the Ivory Towers. We know that the soaring pinnacles of the ivory towers are the symbols of our greatness, of the audacious, indomitable, insatiable curiosity about the "go of things" that makes the scientific life worth living. We know, too, that they are the couplings through which we condense, from the vastly empyrean, that great river which nourishes a civilisation eternally dependent on technological applications of scientific work which was carried out solely for intellectual and æsthetic satisfaction. We believe that the release of nuclear energy is the highest achievement yet reached by the human intellect. We believe passionately in academic freedom.

'But we believe in informed and responsible academic freedom. We ask only that the walls of the City of the Ivory Towers be not so blindly defensive that they leave no windows from which its always fortunate and often inspired citizens can look down on the plains below, no openings through which they can hear the voice of the world around them. The walls will not exclude the bureaucrat, but they may well cut off the view of a landscape where the river of their inspiration has made shapeless patches of adjacent drought and inundation; may well cut off the cries of those now dying of thirst as they mingle with the cries of those in immanent fear of drowning. We, who see some beauty in the geometry of planned canals, seek irrigation in place of inundation, but we do not propose a forced levy in the Ivory City. We do not fear that mute inglorious Newtons will be chain-ganged in operational research; I have known some near-Newtons, but none of them mute, and I have the utmost confidence in their finding their own ivory pinnacle.

'We ask only that those of us, of modest competence, who feel that the rocks may crumble beneath the Ivory City be given the academic freedom of operational research to measure the facts, the dangers and the towering possibilities. There are those who, with fuller knowledge and the free exercise of wisdom and conscience, decide—and usually rightly—to remain in the Ivory City, while others, on the same knowledge and in their own wisdom, choose to dig the irrigation ditches of the Great Strath. We shall dig from a blueprint drawn by ourselves and our peers—a blueprint which we take leave to amend as we dig, and throw away when a better emerges, whether from the free play of imagination and inspiration or from the laborious rubbing of mind upon mind, made tender by a short-term social consciousness no less worthy and far less comfortable than that long-term consciousness for which we desire to make our troubled world, more safe, more appreciative and more encouraging.'

Dr. O. H. Wansbrough-Jones, O.B.E.

DR. WANSBROUGH-JONES (Scientific Adviser to the Army Council), who spoke on the contribution of operational research to the Army in war and peace, said he thought that the sole good reason for retaining the term 'operational research' in place of the term 'method research', which was in general use in the War Office, was to keep the goodwill of the trade name.

No originality could be claimed for the method. It was not so far removed from the method recommended by Newton for improving navigational technique, or from the current methods in use in the Army for planning, especially administrative planning, though it had improved a little on both. It should have improved on the former, by the introduction of better statistical and other scientific tools; on the latter, by giving greater freedom both in opportunities of direct observation and of freedom from daily routine.

A charge of scientific arrogance should not be laid against those who did the work and rightly claimed successes for it. It was a necessary but not a sufficient condition that they should have been scientists; for their scientific training, without doubt, provided them both with a certain specialised knowledge which was often called upon, and a realisation of the meaning of and necessity for an objective approach. But it would not have been sufficient if there had not been a readiness in the Army at all levels and especially at high levels to receive, absorb and encourage these scientists and to heed their results, if there had not been a few outstanding scientists to lead the work, as well as a sufficient body of scientists with a good knowledge of the tasks and difficulties of the Army obtained by serving in it or with it and, pervading it all, the intense stimulus of national need.

In the early days of the late war, a small group of scientists were charged with the study of the problems arising during the operational use of radar equipment and the scope of this work was extended until methods were devised of collecting data from A.A. gun-sites in action. The subsequent analysis of this data yielded some very useful results

on siting, layout and methods of use of A.A. guns and fire-control equipment. It became clear that objective studies of this sort, carried out by men with scientific training but not necessarily possessing any special knowledge or experience, would be worthwhile in other fields.

At home, sections were formed to study tank gunnery, field artillery, infantry weapons, and several other fields, the process culminating in the provision of a further six sections to work in theatres of operations. Up to the end of 1945, some 365 scientists all told had been employed in operational research on behalf of the Army, those at home actually working under the Ministry of Supply and the overseas sections under indirect War Office control. The maximum number employed at any one time was about 174. Up to this date they produced some 380 reports or papers of varying importance roughly equivalent in size to the average scientific paper ; nearly 600 memoranda, which were of somewhat smaller importance, besides dealing with a very large number of day-to-day queries. This scientific force is now very much reduced.

The section with 21 Army Group had a maximum strength of 12 scientists. It was in the theatre of operations from D-Day to July 1945, during which time it produced some forty reports. They covered a variety of subjects, most of them suggested by the scientists themselves : the first list of subjects selected as of greatest likely promise being the location of enemy mortars, the distribution of hits and penetrations in our own and the enemy's tank casualties, and the influence of this on tactics, the performance and best method of use of the PIAT, the problem of dust on roads and airstrips, and the examination of mud. In addition, work was to be continued on two of the basic problems that exercised operational research workers at all times and in all theatres, the basic problems of bombardment, by air or artillery.

This was a very long list, and in practice it was not completed. Dust was taken over by the Air Force. Mud was altogether too variable, and the results must have been too late to be of value. The PIAT work proved mainly technical and was left primarily to the technical Weapons Staff, with some assistance on the planning of trials ; but the mortar location and tank casualty work was completed with good results. The report on the first was the factual basis of the counter-mortar organisation later set up within 21 Army Group ; the report on armour was welcomed as one of the first ever to provide accurate data on how armour should be distributed on tanks fighting in close country. Events, however, led the operational researchers back to the main problem of bombardment, and the work was extended to the study of the effects of close support of medium and fighter bombers.

Work on air support took the form of studies of a number of operations all carried out at the time of the operation and all designed to relate three factors, viz : (i) the total tonnage (and types) of bombs dropped ; (ii) the number and types of bombs arriving in each target area ; (iii) the effects achieved. The last of these factors included : (iv) casualties caused ; (v) damage to defences, equipment and communications ; (vi) effect on the morale of the defenders.

The technique ultimately was first to study the plan : to observe the bombardment itself, then to measure, by intensive and detailed study of the battlefield, the physical effects caused, to attempt by interrogation of prisoners to determine the immediate and longer term effects of the bombardment on their morale, to consider the speed at which the battle developed, and to try to relate the thousand and one special seemingly irrelevant points that arise in the confusion of a modern battle.

Accurate quantitative assessment of these effects is extremely difficult even when observers can reach the target area very soon after the bombing. Even yet, no way has been found of measuring 'morale'. Again, any one operation could not yield data on all these points. For these reasons the results achieved were in some ways inadequate and not always conclusive. However, this was the first attempt at an objective assessment of the effects achieved by a given weight of bombing in support of ground troops, and it did provide a valuable basis on which to plan such operations. Previously there was no factual basis for such planning, only opinions based on experience, opinions that were not always unanimous.

Other work undertaken by the 21 Army Group section, included assessment of the effects of artillery fire, the study of armoured movement, a detailed factual assessment of the claims of tanks destroyed by air attack, a single incursion into the administrative field, and studies of the effects of tank and anti-tank guns.

The operational research section with 14th Army in Burma, applied itself mainly to studies of organisation and supply, two examples of its work being the determination of maintenance tonnages, and studies of manpower wastage.

Owing to the special circumstances of terrain, communications and hence of transport scales, etc., no statistics were available from which to estimate the daily requirements

per division of supplies, petrol, ammunition and so on. This investigation aimed at producing these statistics and succeeded in showing how the total daily maintenance tonnage and its detailed breakdown varied with rate of movement, strength of the division in men, guns, vehicles, animals, etc., type of terrain, etc. This was a straightforward piece of fact-finding, although some of the facts proved somewhat elusive.

The object of studies of manpower wastage, was to assess the rates of wastage of manpower due to various causes—battle casualties, sickness, repatriation, leave, etc., so that the provision of reinforcements could be efficiently planned. The investigation was of some magnitude, since it involved the tracing of samples of evacuated sick and wounded to determine the average time of absence from the unit, a study of the reinforcement system to assess the time spent in transit by reinforcements and a study of operations to derive a numerical index for the amount of fighting done by a division to which the battle casualties and hence the reinforcements requirements could be related.

The results of these two studies were applied to the administrative planning of the assault on Malaya and Singapore. Since, in the event, that assault was unopposed, there could be no ' follow-up ' of the work and the application was therefore limited, and its value was not fully tested.

With the end of the war came the setting up of a permanent peace-time operational research organisation. Its field of work has intentionally been made a very wide one, the following subjects being specifically mentioned in its charter. The scientific study of: (*a*) the soldier and his weapon or equipment and clothing as a combination with a view to increasing efficiency; (*b*) requirements for new weapons and equipment; (*c*) military training, its content and methods; (*d*) problems of supply, maintenance, etc.

In time of peace, the emphasis falls on training and administration. But before embarking on these, it was obviously desirable that information collected during the war should be exhaustively studied and all possible lessons learnt and recorded while this information was still readily available. The first year following the end of the war has been devoted largely to this task. A number of battle studies of the type made by 21 Army Group O.R.S., but with a wider scope than was possible in the field, have been made. These post-war battle studies are now coming to an end and a start is being made in the fields of training and administration.

Amongst the problems to be attacked, for which there is all the leave and encouragement required but too few of the men, are the study of the primary motive in the Army, the acquisition of knowledge and skills, the combination of efficiency for war with economy of manpower and so on.

In conclusion, Dr. Wansbrough-Jones said the following about the operational research worker: ' I think it will really be agreed that he must be a scientist. Secondly, that the problems he has to tackle are difficult problems; so that to be successful, he must have very good ability. It follows, that he must be a good scientist; and the notion with which I am sometimes confronted, that almost any degree of scientific training is adequate for operational research, and that real specialised knowledge is not required and is wasted, seems to me to be false. I agree that he will generally not use his advanced special knowledge; but I do not see how, in general, in our present system, the man can have gained the general research knowledge and experience that is essential without at some time also having gained special knowledge of one field.

' The point then arises, whether it is justifiable to divert these young scientists, for I believe they are at their best when young, from the laboratory at a time when they may be at their most fruitful. I believe that for some, those who are really interested in the social applications of science, and for not too long, it is not only justifiable, but desirable. The great majority of those who worked in this field during the war have now returned to their laboratories. I believe they will sooner make up the leeway in their own academic field than lose the richer experience of men, of affairs, and the social and practical aim of science that they acquired in the war years.

' I believe, that with adequate safeguards, and good career control, it would be an advantage to many young scientists to leave their university laboratories for a period in, say, their late twenties, to work for a year or two for a Government Department; to leave industrial laboratories to work on the scientific planning sides of their industries, and defence laboratories to work with the Services. The Army has plans for the last, which are being put into force. But these young scientists should generally return to their laboratories.'

Prof. S. Zuckerman, C.B., F.R.S.

SPEAKING on operational research and strategic planning, Professor Zuckerman said that, in his essays on ' Generals and Generalship ', Lord Wavell advanced the view that the first requirement of generalship was not a flair for tactics and strategy, but a capacity

for administration, and he emphasised how complicated military administration had become with modern technical developments in armament, wireless, supplies, and so on. Lord Wavell implied that ignorance of new military techniques could hardly be associated with good tactics, nor good strategy with an unreal conception of what is tactically and administratively possible.

To guard itself against some of these dangers the High Command has developed the numerous specialist and technical branches which characterise the armed forces of to-day. The R.A.F., for example, consists of a body of men who in the exercise of their profession depend on a highly-complicated machinery that has been developed out of scientific advances. As a Service it ensures that the men who plan and do the actual fighting understand how to use the equipment with which they are provided, and that it is adequately staffed with men competent to maintain and develop this equipment.

The extremely rapid pace of events, and particularly of technical development, in the recent war, showed, however, that this was not enough, and that in addition to knowledge of scientific techniques and apparatus, it was necessary, if serious waste was to be avoided, to apply the objective and quantitative methods of scientific thought to the analysis and planning of actual operations. Operational research was born of this need, and was applied at not only the technical and tactical, but to a small extent also at the strategic level.

At the technical level its main purpose was to enquire into the performance of weapons and equipment under operational conditions. One example of such an enquiry in the armament field, was to discover the ways in which casualties occurred in air raids, and to determine which effects of explosions were the most dangerous. To answer these questions, it was necessary to carry out laboratory enquiries, as well as surveys of actual bomb incidents. These studies provided a quantitative measure, previously lacking, of the relative danger of explosive effects such as blast and bomb splinters, and of such secondary effects of explosions as the demolition of buildings. Another outcome of these researches was a method for estimating the relative destructive power of bombs of different size, and as a result it became possible to provide answers to such questions as : 'Will one 4000 lb. bomb kill and wound more people than eight 500 lb. bombs, or two hundred 20 lb. bombs ? '

The essential techniques employed in reaching solutions to such questions were the same as those used in the analysis of any complex social problem—first the definition of the relevant variables, and second the estimation of their relative significance.

The introduction of operational research into the tactical sphere was, in the first place, an extension of the radar problem. Sir Robert Watson-Watt was responsible for the brilliant work of development which transformed radar from a laboratory discovery to the sensory system on which a modern air force relies. When he started on this work there was nobody in the R.A.F. who could foresee clearly the operational problems that were to arise. It became necessary to attach civilian scientists to the R.A.F., in order to introduce the new techniques, and to take them through their technical teething troubles, and scientists were soon asked to enquire into the tactical use of radar under practical conditions. This need arose because very few operations officers in the Service were versed in the analytical methods necessary to judge whether or not radar was being used in action with the maximum possible effect.

Scientists, with their understanding of the techniques involved, and with their appreciation of the tactical problems that had to be overcome, could, in the case of radar, arrive at valid decisions about tactics which could only have been accidentally derived by other methods. This is equally true of the quantitative studies that were made of the relation of different types of formation flying and different tactics to the accuracy of bombing, to mention only one more of numerous examples where scientific method was applied by operational research sections in the solution of tactical problems.

What is most usually understood by the term operational research in war is a type of scientific enquiry which can provide information useful in the planning of new weapons, or of new tactics, or of improved organisation, both in offence and defence. The subject-matter of war-time operational research was quantitative. The information provided was also representative, as it was based on unselected material relating to the situations under enquiry. Further, it proved to be extremely valuable information. Thus, in so far as scientific intervention was a determining factor in the development and use of radar, operational research played a vital part in securing us from defeat. And in so far as operational research was an essential factor in doubling the accuracy of bombing, the effort of one small group of men working at the problem achieved as much from a national point of view as a doubling of the production of bombers and crews.

Without the consistent help of expert scientific knowledge, war-time executive Departments such as the Ministry of Food, the Ministry of Home Security, and the

Supply Departments would not have been able to develop and implement their major policies, but on the political and military plane most major operational policy was determined independently of scientific advice. The Scientific Adviser to the Prime Minister was no doubt able to bring scientific method to bear on decisions which affected major war policy, and examples may be quoted of scientific analyses of operations which influenced major strategy.

The defeat of the German submarine menace had far-reaching effects on the build-up of supplies and forces in Great Britain, and therefore on the strategy of the war as a whole. The part played by scientists in this campaign was to provide exhaustive analyses of its course and tactics, and to show what the probable outcome would be of alternative courses of action. This work not only helped to determine the convoy system, but also assisted in showing the value of applying 'very-long-range' aircraft to the task of anti-U-boat patrols.

Before the spring of 1944 most of the heavy bomber effort of the R.A.F. was applied to the destruction of German cities, while the heavy day bombers of the American Air Forces concentrated the greater part of their attacks on German aircraft factories. Reports on the effectiveness of these two offensives were provided through various Intelligence sources. But accurate measures of their progress could only be derived from aerial photographs. A study of the relation of air-raid destruction in England to losses in our own production had, however, provided a means, even if an unprecise one, of assessing the functional significance of the material destruction of German cities, and by the end of 1943 it had become apparent to some that the economic effects of urban devastation in Germany were not as great as had been hoped for. At the same time, an analysis of the effects of bombing in Sicily and Southern Italy, carried out on the spot after these territories were occupied, showed that attacks on railway communications were associated with very rapid and very profound economic and military effects.

On the basis of these objective studies, the Allied Strategic Air Force was directed to the bombing of railway targets in France, the Low Countries and Germany, but not without opposition from advocates of the strategic policy of continuing the 'blitz' on German towns, and also by those who advocated the bombing of German synthetic oil plants.

As it turned out, there was sufficient bomber effort available to attack both communications and oil. A post-war survey of the results has shown that both offensives had remarkable and far-reaching results. The widespread and critical collapse of German war industry which began abruptly in the autumn of 1944 was essentially due to the destruction of the communications network, while the bombing of synthetic oil plants led to a fall in the output of oil products serious enough to affect Germany's immediate military plans, and potentially her power to wage war at all. The survey also confirmed the conclusion that the destruction of urban areas was only a minor factor in depressing the level of German production.

This example of the application of operational research to a strategic problem pointed the clear moral that, provided it was possible to assess quantitatively the relative value of the main components of complex situations, an empirical attitude, and scientific method, were likely to be more valuable than a purely theoretical approach in the determination of policy.

Professor Zuckerman said he did not believe that operational research was a discipline *sui generis*. It was no more than the application of ordinary scientific methods of thought, or controlled commonsense, to the analysis of complicated and dynamic problems. It should be recognised as no new thing. In a primitive sense it was something that was done in every sphere of activity.

The war-time establishment of operational research sections manned by scientists was an indication that, at the time, the Services realised that they did not possess within themselves the necessary scientific experience to analyse the operational use of new techniques or the tactics based upon them. It was to be hoped that, as a result of the experience of the recent war, the Services would remember that scientific methods of analysis were every bit as valuable a weapon as the new gadgets science produced.

The following paragraphs are quoted direct from Professor Zuckerman's paper :

'Scientific method in the elaboration of policy is as vital to-day as it was during the war. The present political and economic state of our country or of Western Europe does not allow of unfettered individual enterprise, any more than did the war. What one means by the best strategic policy in war is the policy that will most readily lead to victory or prevent defeat. With the world in its present state, what one understands by the best strategic policy in peace is that general pattern of action that will best serve national or ideological interests. The declared strategy of the present Government of our country is to carry socialist doctrine into practice at the same time as it restores our economic fortunes. It has taken over the responsibility, through nationalisation, for

such basic social services as power, transport and health. It also controls, less directly, food supplies, building, and production in general. It has thus added to the normal administrative function of Government, executive duties which demand that it appreciates the technical background of the many activities that it now controls. Its overriding task is to stimulate the rapid expansion of coal and agricultural production, and of exports. As with major strategy in war, the greater the weight given not only to the political and economic but also to the technical and scientific variables which can affect the situation, the more successful will be the grand strategy that the Government adopts in the discharge of its new functions. This seems to me to be an inevitable consequence of the replacement of individual by State enterprise, and of the extension of Governmental responsibility into executive fields that are dominated by scientific and technical factors. If we are to retain any position in this world of competing national and social interests, it seems equally inevitable that Departments of State will have to concern themselves more and more with the long-range control of social services and of economic activities. This appears less a question of Socialism than, situated as we are, one of pure necessity.

'If Departments of State are to fulfil their responsibilities adequately, their officials will either have to lean more and more upon scientific advice, or become more and more scientific themselves. Unfortunately, however, science is not in as favourable a position to serve in peace as it is in war, when the main instruments of national policy are the armed services which, in the discharge of their responsibilities, have a more obvious and closer need of the scientific and technical world. During peace we also, unfortunately, lack the unity of purpose that characterises war. Moreover, the recent revolution that has occurred in the function of Government, and the sudden change in our economic fortunes, can hardly be expected to have been associated with a widespread process of metamorphosis among our Civil Servants. Their functions and responsibilities may be vastly different, but they are still the same men, and hitherto they have not found it either necessary or useful to seek scientific advice on any large and organised scale.

'Such Cabinet planning bodies as that presided over by Sir Guy Plowden may perhaps be regarded as operational research sections that have had to be established at a strategic level in the national economic field, because of the difficulties of the present situation. So, too, can the Advisory Council on Scientific Policy, presided over by Sir Henry Tizard. As the situation develops, it seems probable, and it is to be hoped, that such bodies will find a common meeting-ground for the exposition of the major economic, scientific and administrative problems that have to be taken into consideration, together with political factors, in the elaboration of fruitful peace-time strategy. I am not suggesting that scientists could provide any easy solution to the country's critical economic position, any more than I believe that the economist has any ready solution. What I believe is that planning committees might gain if they included scientists who could bring scientific method to bear and who could intervene on the basis of special knowledge of the scientific and technical variables affecting matters under discussion. The promised development of atomic energy plants, for instance, will completely transform, as have other advances of science and technology in the past, the content of political and economic situations.

'But do not let us overestimate the speed or underestimate the difficulties of getting scientific advice and method to bear widely on the urgent economic problems of to-day. During the war the task was relatively simple, because, as I have suggested, of the unity of our purpose, and because of the concentration of power in the services and in such executive civil ministries as agriculture. It was simple, too, because our military leaders recognised the value of introducing scientists into professional, scientific and technical fields not their own. To-day the position is vastly different. The Government has only started on its overall control of national enterprise, and the actual pattern of its control is still to unfold. There is no organisation, other than the official scientific departments, into which scientists could be fitted, and through which they could start on a broad front to enquire into the scientific and technical desiderata of policy. Science has a hard path to follow if it is to play any major part in the determination of strategy in peace. But this fact does not make the task any less necessary.'

Prof. W. C. Wilson

PROFESSOR WILSON described the work of a Medical Research Section, which consisted of Dr. A. L. Chute, Dr. E. T. C. Spooner and himself, in the Middle East between May 1942 and April 1943. Their task was to inform the War Office and the Medical Research Council on problems affecting the health of the troops, their mandate covering all matters concerning the welfare of fighting men in a very large territory with several distinct and varied climates; and the difficulty was not to find problems but to select the most important ones. Their duty was to collect information,

not to do research ; to define the problems, not to solve them.

Dr. Chute, a Canadian physician and a trained physiologist, dealt with tank problems. During the disasters and the long retreat to El Alamein of June and July 1942 he visited every tank unit in the Western Desert. Without transport of his own he travelled mostly with Field Ambulances and took an active part in the evacuation and treatment of casualties. His reports gave extensive factual data on wounds, evacuation of wounded, fatigue, effects of stress, hours of sleep, food, appetite, cooking and other aspects of tank fighting in this battle. In an analysis of all the casualties of one tank regiment he detailed the time, place and mechanism of wounding, the evacuation and disposal of every man killed or wounded and the fate of each vehicle. His conclusions made a strong impression on G.H.Q. Middle East and many of his recommendations were adopted at once. His work was of great value to tank units at a particularly difficult and anxious time and it bore good fruit in the successful battles of the autumn of 1942.

Dr. Spooner, a bacteriologist, who had investigated ' hospital infection ' of wounds in 1940 and had run a London Blood Transfusion Sector during the ' blitz ' of 1940–41, undertook a general survey of Middle East conditions and made contacts with medical, combatant and training units in the Army, Navy and Air Force, as well as with civilian medical services in Egypt, Palestine and Syria. He surveyed the typhus situation in Egypt, later keeping contact with the American typhus commission; he studied desert sores and, particularly, the epidemiology of the outbreak of infective hepatitis which seriously depleted the 8th Army in the later months of 1942. He took a course of parachute jumping and reported on its medical aspects, studied the distribution of wounds of the trunk, against which body armour might have given protection, organised a proper trial of body armour and investigated blood transfusion reactions.

Professor Wilson's work was confined to the problems of burns and ' wound shock ' which caused much concern at the time. The most important aspect of burns, that of prevention, received too little attention, and if the deadly ' desert stove ' could have been abolished and the gross misuse of petrol prohibited, the problem would have been much less serious. The same holds for civilian life, where most burning injuries, especially severe and fatal ones, are incurred in the home and are preventable. Much thought and concentration on prevention are urgently needed, and that is more a matter for engineers, architects and educators than for medical men. The work on ' wound shock ' was in the nature of a reconnaissance and the subject was studied more fully later in Italy. The problem of ' wound shock ' was solved very largely, though perhaps not completely, by the development of blood transfusion services.

Professor Wilson referred to the shortage of trained investigators in the medical sciences which proved a serious handicap during the war. For the progress of medicine it was important that the supply should be increased, but he was not so optimistic as some who thought that the shortage of trained investigators in the clinical subjects could be easily or quickly remedied. Most gifted research workers naturally turn to the basic sciences and only a minority to clinical subjects, and of these some are lost to research because they soon become fully occupied with clinical practice and teaching.

It was easy to forget that research in medicine was many-sided and that new fields were waiting to be explored and new methods to be tried. Among practitioners of medicine there was a widespread interest and a desire to participate actively in the advancement of knowledge. In the Middle East much material was obtained by young officers of forward units, often with the expenditure of much time and labour. Florey and Cairns found plenty of young men in North Africa who were able and willing to take part in investigating the rôle of penicillin in wound treatment. If the latent forces of interest and idealism in the medical profession could be mobilised they might provide a research weapon of immense power for use in some new fields, such as social medicine. But voluntary co-operation must be sought ; anything in the nature of compulsion or Government regulation would defeat its own ends.

Prof. F. A. E. Crew, F.R.S.

SPEAKING on operational research in social medicine and biology, Professor Crew said that experience had revealed once more that, in a protracted war for which a nation was unprepared and into which its total resources must be flung, there were two phases in the encouragement of scientific research for military ends. In the first phase, the major problems besetting the General Staff were those arising from the production in ever-increasing quantity of machines and materialities of ever-expanding ingenuity, precision and lethality. In the second phase, the problems were those relating to the quantity and the quality of men, to their health, morale and efficiency.

The fighting services, neglected in peace, first leaned heavily on the applied physical sciences for the provision of weapons and equipment. Later they found themselves

forced by shortages of manpower to turn to the biological and social sciences for the satisfaction of their most urgent requirement, the provision of men who could make the fullest possible use of the things with which physical science had so abundantly endowed them.

The longer a war lasted the greater became the relative importance of the department of the Adjutant-General which was concerned with the soldier as a human being and attempts to satisfy his biological and social needs. It was only in the second half of a sustained war that his medical, welfare, selection of personnel and other directorates were urgently expected and encouraged to make their maximum contributions to the war effort.

In the circumstances which prevailed at the begining of the late war it was inevitable that the Army, completely absorbed in the stupendous tasks of abrupt expansion and outfitting, should withhold encouragement from the biological and social sciences and cater for the present rather than for the unknown future. The experience and total resources of the Medical Research Council were placed at the disposal of the Army Council at the very beginning of the war. It was expected that any problem of urgency and military importance which fell into the sphere of the biological sciences, would be referred to the Medical Research Council who would then take whatever steps were necessary to ensure that the appropriate investigation was undertaken. But this arrangement simply did not work, for the apparent reason that no problem of this kind could at this time command the sufficient attention of the Army Council.

Sir Edward Mellanby ultimately created a field investigational organisation consisting of operational teams of various design and composition which were sent out to different theatres of war, there to recognise and define the outstanding problems of a biological nature and of military importance and to report back to a Military Personnel Research Committee with a multiplicity of sub-committees, each consisting of selected representatives of every branch of scientific activity and of industry which impinged upon the problem, together with representatives of those branches of the fighting services most affected by the problems under consideration. Prototypes of these operational research teams were those commanded by Professor (then Lieutenant-Colonel) Wilson and by Major Chute of the R.C.A.M.C. In addition special scientific teams together with all the necessary laboratory and other equipment were formed for the carrying out of fundamental work of a kind that could not be farmed out to any existing university department or research institution. Examples of these were the Tropical and Jungle Warfare Research Unit at the National Hospital, Queen Square, London, under Dr. E. A. Carmichael, and the Armoured Fighting Vehicles Research Unit at Lulworth under Professor Ivan de Burgh Daly.

In the later years of the war, research organisations of this kind were created in Australia, Canada, South Africa, India, and on the grandest possible scale in the United States of America. Between all these organisations there developed the fullest and freest interchange of information. It was impossible to assess the true magnitude of the benefits which accrued from this pooling of knowledge and experience, but the work would claim a prominent place in the Medical History of the War, when it came to be written. When, in due course, the Army found it possible to encourage and to undertake research of this kind on its own account, to appoint its Scientific Adviser to the Army Council and its Director of Medical Research, the M.R.C. organisation was the model for what they created and did, and those who were involved in these developments would never cease to pay tribute to the vision, the constant stimulus and the vigorous support of Sir Edward Mellanby, and to the magnificent example of such men as Chute, the Canadian, the notable first of those who made tanks fit for men to fight in.

Summarising the lessons that were learnt and which had their bearing upon similar research activities in peace, Professor Crew spoke as follows :

(1) If problems of immediate importance to a community and of a practical nature are to be attacked at all hopefully by the application of scientific method, there must exist a great reservoir of scientific knowledge of a fundamental kind awaiting application to current circumstances once these have been defined.

(2) The nature, even the existence, of a problem of quite serious importance, can remain unrecognised in a community until highly trained scientists specially selected and equipped to recognise the problem and its essence, to collect orderly accurate data and to deduce the correct results are sent into this community.

(3) To the trained scientist, a problem which, though unrecognised, is seriously vexing a community quite commonly turns out to be one of relative simplicity in its definition but complex in nature. No one man trained in a single scientific discipline

is competent to tackle it alone. A mixed team is required, compounded out of biologist, entomologist, physiologist, medical man, psychologist, physicist, statistician, gunner, infantryman, parachutist, etc., etc., the exact composition of the team being determined by the probable nature of the problem and the general circumstances which obtain within the community.

(4) Research of this kind can be carried out hopefully only when the community being served has itself come to appreciate the nature and importance of the problem, to feel the need for its solution and is willing, if not eager, to participate actively in the investigation.

(5) The results of any investigation of this kind, no matter how great their potential value, can remain disregarded or unapplied unless and until their significance is thoroughly appreciated and their application strenuously encouraged by those on the topmost levels of the community for whose benefit the investigation is being conducted.

(6) For the rapid solution of a problem of current importance in the medico-biological field, it is a very great advantage if arrangements can be made whereby the same problem affecting different communities in different circumstances can be attacked in the different places by different teams, whose activities are co-ordinated by some high level scientific mechanism.

In developing the thesis that lessons learnt in war could be applied directly to the conditions of peace, Professor Crew emphasised that during the war the Medical Research Council interpreted the term 'medical' exceedingly widely and encouraged so many activities not strictly medical that there was hardly a problem in the whole field of social and human biology and relating to the health, morale and efficiency of men, which did not come under the survey of one or other of its sub-committees. As an instrument of government the Medical Research Council, through the Lord President, could recommend action at the highest level to ensure that scientific discovery was immediately and sufficiently applied to human and social affairs. The M.R.C. and other grant-giving bodies were in a position to mobilise qualified medical and other scientists in sufficient numbers and to permit them to carry out their work in ideal circumstances within university departments or research institutions to which field investigational teams could readily be attached. If, with the return of peace, the M.R.C. should find it necessary to withdraw from the field of human and social biology and to restrict its interests solely to the province of medicine, then Social Medicine, now hailed as a new development in or an expansion of medicine, would be greatly hampered in its growth. It was certain that Social Medicine could not flourish unless field investigations very similar in kind to those undertaken in war by the operational research sections were sent out into the community, unless problems of health, morale and efficiency receive the same attention as problems of disease, and unless the concepts and techniques of sociology were added to the armamentarium of medicine.

Mr. Louis Moss

MR. MOSS, Director of the Government Social Survey, said that the Social Survey was a technique whereby precise social data, i.e. information about human beings and their social environment, could be collected and analysed. It consisted basically of an application of the scientific method to the social field. The Government Social Survey Unit was one of the several bodies now engaged continuously in such work. It was created during the war years to meet immediate administrative needs and had now been established as a permanent Government Social Research Unit.

Early enquiries made by the Survey reflected immediate administrative needs. Examples of the work undertaken were : for the Board of Trade, regular studies which helped to estimate the extent of shortage of scarce resources and to determine which sections of the population and in which parts of the country were most affected ; for the Ministry of Food, surveys of food consumption and expenditure in order to follow the effects of food and price policies on nutrition and family food budgets. This work not only provided information required for immediate administrative purposes, but produced basic data suitable for the study of research workers in economics.

The need for complete mobilisation of manpower required the development of techniques capable of assisting in the formulation and administration of recruitment policy for such organisations as the A.T.S. and nursing : social surveys also threw light on the attitudes of women to work in industry. Techniques thus developed and information thus obtained were of direct interest to sociologists and social psychologists.

About the middle of the war period there were reports of an increase in the amount of

minor illness in the general population. The Ministry of Health asked the Government Social Survey Unit to develop a method of measuring the amount of illness in the population as a whole. A successful technique was developed and was now the basis of a continuous 'Survey of Sickness,' which provided this country with better information about the general health of the population than was available in any other country of the world.

In another field the Survey was used to measure the success of the various media used by Ministries, such as those for Health, Food and Information to stimulate voluntary effort by the people during the war. In this connection an enquiry into the effectiveness of a campaign to raise the technical level of agriculture led to a study of the educational background of the agricultural community, and provided perhaps the first up-to-date information on the social composition of the farming group.

Short-term surveys were later followed by work designed to assist administrations concerned with the development of long-term policy which included studies on heating and lighting of dwellings, town planning, attitudes of the population towards education, etc.

The particular contribution made by the Social Survey during the war years was to provide administrators with the kind of information which could only be obtained by direct contact with the public and by a technique capable of fairly precise estimation of social needs on a national scale. It was worth emphasising that, in adapting itself to these functions, the Social Survey technique was being developed into a scientific tool capable of advancing the work of social scientists in many fields.

Physical scientists often criticised social scientists for their failure to develop observational techniques and for their willingness to draw conclusions on what, in other fields, would be considered an inadequate factual basis. There were some who said that the social field was such that scientific method could not be applied. They claimed that it was impossible or difficult to make objective studies in the social field because of the personal interest of the investigator in the subject matter under investigation. It was also said on occasion that the difficulties of carrying out controlled experiments in the social field limited the possibilities of scientific method as usually understood. Controlled experiment consisted in the observation of the subject matter under known varying conditions, that is to say when the investigator was able to recognise and measure the effect of variations in such conditions. Providing the effects of the major variables could be recognised and measured there was no reason why results similar to those obtained in the field of the physical sciences should not be expected. Modern statistical techniques provided methods whereby the influence of particular variables might be parcelled out.

Once in a position to specify the effect of different social variables the social scientist approached the possibility of prediction in the social field on as firm a foundation as the physical scientist in his field. Social surveys used in conjunction with modern statistical techniques could help the social scientist to make great advances.

Great Britain now faced one of the most critical phases in its history. It was likely that benefits would follow in the short run from the application of the results of past physical research and the efficient utilisation of human resources. An advance in either direction presented immediate problems in the field of social science. Both required the application of scientific method to the field of social organisation more than anywhere else, and social science now had great opportunities of serving the nation.

Some directions in which social science could help were, studies of social and industrial conditions of work in, and attitudes of potential recruits to critical and undermanned industries ; the distribution of scarce consumer goods which should meet basic needs and play their part as incentives at critical points in industry ; the effect of priority schemes and developments such as differential food rationing on different sections of the population ; the flow of consumer expenditure, etc.

In conclusion, Mr. Moss said that the social survey and other social science techniques were at a turning point in their development. In so far as they made a substantial contribution to national needs in the years ahead then, to that extent, would the status of social science be advanced and the frontiers of the scientific method pushed forward to the lasting benefit of human welfare.

Prof. J. D. Bernal, F.R.S.

PROFESSOR BERNAL, speaking on operational research in peace, said that the same needs that led to the appearance of operational research in war should now lead to converting that experience for peaceful uses. The situation in which the country found itself, with its large gap between imports and exports, and particularly the impossibility of feeding itself from its own land, was at least as serious and immediate as any in the war, and was, in addition, one that would have to be faced for many years to come. An attempt to meet it simply by urging people to work harder and longer hours could not possibly

solve the problem. The only way was by improving technique, and the need for improving technique when only limited resources of men and material are available, was precisely the condition that called for operational research in war. Many people said that what could be done in war was impossible in peace ; but this was no ordinary peace. Others, fully alive to the crisis, said it was too late to use science at all—that science was a long-term enterprise and that we must now rely on immediate expedients and traditional modes. We were likely, however, to be faced in the next few months and years with a series of abrupt changes in the basic conditions of our existence ; with shortages of traditional materials and of trained labour ; with the need to do new things quickly : all of which could not be met effectively by unscientific improvisation. Since the operations of peace were more complex than those of war, and there was less experience of running them in an ordered way, the technique of operational research would be needed, to find out what had to be done, to check the success of what was undertaken, and to modify its conduct as it proceeded.

The application of operational research was at the same time a large-scale strategic and a small-scale tactical job. We knew we had limited resources in manpower and material, and particularly in trained manpower in engineering and science. It was absolutely essential that these should be used in the most effective way by means of a scientifically determined system of priorities, which took all the circumstances into account, and weighed not only our present resources, but also possible increases in those resources, often by very large factors, through the application of high pressure scientific research and engineering development.

Only a combination of economists, engineers and scientists could achieve this ; but they must operate on the level of the highest planning authority in the country. The speed at which we set about doing this would depend on the availability of the men and techniques with which to do it. It was not even so much a matter of getting trained men, but of mobilising them quickly in the most appropriate positions. A much greater sense of urgency was needed. But the first task was to establish the main priorities. Some seem obvious enough—coal, power, steel, transport and food—but others, such as elimination of chemical waste and increase in productivity in the textile industries, might be even more important in the short run. Professor Blackett's first principle in assessing priorities, was to do those things which combine the greatest need with the most rapid possibility of achievement. There were some things badly wanted, but difficult to get. There were other things relatively easy to achieve, but which would not take us very far. What was wanted, was to concentrate in the first place on important things that could be done quickly.

This was largely a matter of intelligent phasing of operations, and three phases could be roughly envisaged—the initial phase of recognition of the problem, where little could be done but reallocate materials, cut down imports and generally urge greater production. This might last for the best part of a year. The second phase might be called one of reorganisation, when it was hoped that production needs would be more or less fixed, and we could set to and arrange productive processes in the most effective way, with a certain degree of concentration on readaptation of new products, but without putting any heavy demand on capital expenditure. The third phase, which, if things went well, should be entered somewhere around 1950, would be one of real reconstruction, where productive enterprises using new machinery as well as new methods could be built up. At first sight this appeared to be in the nature of economic planning, not involving science directly. But it should be remembered that the reconstruction phase could never come unless it were preceded by a stage of building of prototypes and development. That should take place during the earlier stages and, in many cases, should itself be preceded by fundamental background research started now. Unless this were done all present discomforts and privations would be to no purpose, and the future would be far more dismal than it now appeared.

Although the bulk of scientific work undertaken now would find its practical result two to five years later, there was still an immediate need for scientific work in the intervening phases, and not only in current operational research. Physical research would be necessary wherever materials and techniques had to be transferred from their present use to some new one. For example, if pre-stressed reinforced concrete were used as a substitute for timber in building, research would be needed into how economically it could be used. Indeed it was practically impossible to undertake any serious change without having at least preliminary answers on the research side.

Among the immediate problems to be dealt with, the first place was taken by fuel and power, and the greatest returns could be got from a saving of existing fuel resources, rather than an attempt to create new ones. By insulation and better management of furnaces it should be possible to save a great proportion

of domestic as well as industrial coal. Similar savings should be effected fairly rapidly in chemical wastes. Our economy in the past had been based on the principle of encouraging the sale of goods, and the waste of goods had helped sales. Chemical products were made with the utmost care and used with the utmost extravagance. A glaring example was sulphuric acid. A ' wardenship of the elements ', ought to be established to see that elements such as sulphur and phosphorus were used as far as possible in a cyclical manner, and never allowed to pass out of our hands. In the steel industry, probably more could be got in the short run out of saving steel from unnecessarily lavish use owing to lax specification than by immediately increasing production.

The shortage of food, however, was the greatest danger, and drastic measures might be necessary. The practice of getting along on the surplus food of other countries was becoming increasingly difficult, as was the habit of relying on these islands for high-grade foods such as milk and eggs, which were produced inefficiently. We might be driven, and we should certainly be prepared, to rely more immediately on vegetable products, and to use scientific technique, already past the research stage, to make use of the proteins available in young leaves. There was nothing more absurd in eating grass than eating lettuce: the only reason this was not done was on account of the fibre content, and this had now been eliminated in the extraction process devised by Dr. Pirie of Rothamsted.

No all-over planning of industrial and agricultural reconversion would be of any use unless there was also lively and effective research work on the workshop and farm level. Operational research in tactics is as important as in strategy. All the ingenuity in the country would be needed to solve the thousand small problems that were bound to arise in our forcibly changed economy. This meant mobilising and organising tens of thousands of engineers and scientific workers up and down the country on regional and local factory problems, and this could only be done, as it was in the war, by a reallocation of jobs. Thousands of scientists and engineers in industry and the Services were at present being used in a wasteful manner, or for purposes of secondary importance. Operational research was needed to find the best distribution of our scientific and technical manpower, and to keep continual check on redistribution as the situation develops.

With our present knowledge of what could be done with operational research, it would be tragic if this one organisational development of the war was not given the chance to show its capacity in the peace.

SECTION H.—ANTHROPOLOGY

DATING THE PAST[1]

GEOCHRONOLOGY is the branch of geology which attempts to date in years those periods of the past to which the human calendar cannot be applied. It provides the anthropologist with tentative time-scales for the physical and cultural evolution of man. Most geochronological methods require the elaboration of a relative chronology, usually in terms of climatic or astronomical cycles, and these in turn are dated. The place within the *relative* time scale, therefore, of the object to be dated must be known. Much work has been done and remains to be done on such relative time-scales, of which the climatic succession of the Postglacial based on the method of pollen-analysis is an outstanding example. There are, however, a few actual and potential methods by means of which the object itself may reveal its age. One of these is the fluorine method which was discussed at the meeting. Another, promising but not yet tried, may be based on naturally occurring, radioactive carbon and yield age-estimates up to 50,000 years.

The discussion on the various aspects of ' Dating the Past ' was introduced by a survey of recent progress in the well-known methods of dendrochronology or tree-ring analysis, varve chronology, Pleistocene chronology, and radioactivity chronology. Mr. A. Leslie Armstrong contributed a paper on the evidence of Lower Palaeolithic man in the north of England and its bearing upon relative chronology. Dr. K. P. Oakley discussed the potentialities of the fluorine method of dating bones, and Dr. H. Godwin reviewed the principles and practice of pollen-analysis.

[1] Report of a discussion in Section H (Archaeology and Anthropology) at Dundee on August 29, 1947.

Recent work on Chronology
By Prof. F. E. Zeuner

Dendrochronology.—The Yellow Pine chronology, used in the dating of prehistoric Red Indian sites, has now been extended back to A.D. 11 by the school of Dr. Douglass. Schulman has published of existing chronologies and a bibliography of tree-ring analysis (1). The method has been discussed recently by W. A. Harwood (2).

Varve Chronology.—The Gotiglacial part of de Geer's chronology has been severely criticised. It covers the Danish Isles and is important for the dating of the Mesolithic. De Geer himself has never published the details of this part of the varve chronology, but Sigurd Hansen (3) spent a number of years on checking de Geer's sections in Denmark and southern Scania. He came to the conclusion that, with the exception of eleven short diagrams (none with more than 35 varves), all Danish diagrams of de Geer, comprising up to 1,000 'varves,' are not annual deposits, but that they represent shorter periods, of *weather*. He therefore regards all correlations between Danish and Scanian varve localities as fallacious. Fortunately he appears to hold that the central Swedish group of varves is of the annual type, so that the classical part of de Geer's work may still be accepted. But the early part of the chronology, and also the morainic cross-connection from Sweden to the Continent, are lost. On the other hand, the Allerød Oscillation, which Danish palaeobotanists have always regarded as one single phase, need no longer be split into several phases on supposed evidence from varve sections. It is significant that another worker, M. Schwarzbach, has also found that not all varves are of the annual type. He studied a Pleistocene series of glacial 'varves' in Silesia (4). It will therefore be necessary in the future to establish that an annual rhythm is present before varve countings are carried out.

In Switzerland, Max Welten (5) studied the finely laminated lake deposits found in the Faulenseemoos near Interlaken. His paper breaks fresh ground since these deposits contain pollen. Welten has fortunately taken pains to establish that the Faulensee laminae are annual. In spite of difficulties arising out of their thinness, the distribution of the pollen grains of a number of tree species within a single varve is in agreement with the sequence of flowering periods of the various species.

There are two types of gaps in the Faulensee series, namely those which are caused by indistinct lamination, often increased by distortion and mixing caused by the borer, and secondly natural gaps due to local erosional unconformities. Welten is confident that such gaps can be closed by interpolation and that the error does not exceed 1–200 years for the entire varve record of the pre-Christian era.

A serious problem was the connection of the counted varve series with the modern calendar. The bog was drained in 1920, but at that time sedimentation was proceeding in a very small central portion only, and material from this portion was scanty and incomplete. On the assumption that the growth-rate of the sediment was the same as in the lower parts of the section, Welten carried out two extrapolations which produced consistent results. But it should be borne in mind that the rate of deposition may well have been slower in the final phase of the bog, in which case the dates would have to be increased.

For the later phases from the end of the Mixed Oak Forest and the early Neolithic onwards, Welten's chronological table agrees with results obtained elsewhere. The earlier phases, however, appear much shorter than they are generally believed to be. This shortening is apparent both in the floral succession and in the sequence of prehistoric periods. Assuming that Welten's varve timescale with its inter- and extrapolations is reasonably accurate, varve deposition would have begun about 7550 B.C. Accordingly, he places the retreat of the ice from this locality immediately prior to this date, which agrees so well with the date obtained for the retreat from the central Swedish moraines and the Finnish Salpausselkä, that Welten correlates the Swiss retreat (from the Jaberg Moraine) with that from the central Swedish stage of the Scandinavian ice-sheet. This is an important result. P. Beck, however, has regarded the Jaberg moraine as part of the Bühl stage of the Alpine glaciation (6), thus implying a much greater age than that inferred by Welten. Since evidence is nowhere in favour of a correlation of the central Swedish Moraine with Bühl (a term applied to a mulitude of late moraines of the Last Glaciation), it is wise not to accept such correlation. Welten, however, does so and is immediately faced with the discrepancy between his own age estimate and the higher one assigned to 'Bühl' on rather insecure grounds. He rightly discards the latter. In doing so he points out that the radiation curves show no minimum corresponding with the central Swedish stage and is, therefore, inclined to discard the astronomical theory also. But the central Swedish moraine has never been regarded as caused by a radiation minimum. It is now explained on meteorological grounds (7, 8). For the same reasons, Welten's results have no bearing on the dating of the Magdalenian of the Rhine valley (9).

The great value of his work lies in the first construction of a varve time-scale coupled with a pollen record.

Pleistocene Chronology.—In recent years, difficulties have arisen in connection with the definition of the Plio-Pleistocene boundary (10). Being a matter of nomenclature only, the definition of geological divisions should not seriously affect research, but in this case terms like Lower and Middle Pleistocene are involved and with them the relative ages assigned to a large number of human fossils and industries. American workers studying Pleistocene and Early Man in India, Burma and Java have lately included the Villafranchian (final Pliocene) in the Lower Pleistocene (11). Such procedure would affect the age of Pithecanthropus, and by implication of Sinanthropus and other important fossils, not to mention that it would cause confusion in the Pleistocene stratigraphy of Europe. Workers in India and Java have refuted this suggestion on geological grounds (12), and physiographical evidence also favours the exclusion of the Villafranchian from the Pleistocene (13). In areas, for instance, where neither faulting nor isostasy has interfered with the raised beaches, marine deposits of Calabrian and Sicilian age (equivalents of Villafranchian) are of a plateau character, whilst the Milazzian (First Interglacial) and later stages are bevels cut into the older plateaus and separated from them by high cliffs. This is apparent on the north coast of Egypt, where in Arabs Gulf five stages of the Sicilian can be recognised, succeeded by a drop which caused a cliff to be formed, with the Milazzian sea-level 25 metres below the Sicilian.

The investigation of raised beaches is becoming increasingly important for the prehistorian. In Morocco, for instance, Neuville and Ruhlmann (14) found Clacto-Abbevillian implements in a horizon dating from the Sicilian regression, and antedating Milazzian deposits. This industry suggests that the Abbevillian hand-axe, a tool-type hitherto thought to be confined to the First Interglacial, is in Morocco approximately contemporary with the First Glaciation. The industry is typologically interesting, not only because it comprises both core-tools of the Abbevillian type and flake-tools made in the Clactonian style, but because many tools are present with a triangular cross-section. It is in deposits of the same age that Reid Moir found some of his rostro-carinates in East Anglia.

River terraces afford another means of investigating Pleistocene sea-levels and of arriving at a relative chronology of the Palaeolithic. The erosional benches cut by the Thames are an example. They have been studied for a number of years by Mr. Day Kimball in conjunction with the speaker. The thousands of wells and borings, nearly all recorded by the Geological Survey, have made it possible to construct profiles, both across the river at suitable points, and covering longitudinally the course from Oxford to Gravesend. The erosional benches of rivers near the sea are adjusted to phases of *low* sea-level, *i.e.* they correspond to glacial phases. As a rule, a complicated system of crossing benches was formed during the Pleistocene, since the heights of the successive low sea-levels varied according to the amounts of water locked-up in the ice-sheets. But in the Thames a chalk-ridge near Gravesend provides an obstacle through which the river was unable to cut quickly. Upstream from it each phase of low sea-level, irrespective of how low it was, initiated a phase of intensified erosion. A series of roughly parallel benches was thus formed. Of these, two have been well known for many years, the Swanscombe Bench (Antepenultimate Glaciation) and the Taplow Bench (Penultimate Glaciation). Between the two, as many as six other benches can be recognised. Below the Taplow Bench, five more can be distinguished, the three lowest forming the bottom of the 'Buried Channel.' These benches are by no means equally developed, and some almost certainly represent only minor phases of low sea-level. Since the buried channel phases are contemporary with the Last Glaciation, these benches seem to afford a fairly complete record of the oscillations of the sea-level since Swanscombe times, a record which may be of use in the construction of a detailed relative chronology, and eventually of an absolute chronology.

As to the Astronomical Theory which has been used in obtaining tentative dates for the climatic phases of the Pleistocene, and thus for the Palaeolithic industries, it should be noted that a large volume was published during the war by Milankovitch in the Yugoslav Academy of Sciences. It is entitled 'Kanon der Erdbestrahlung' and contains all the relevant data on which the theory is based (15).

Independently of Milankovitch, radiation tables were calculated by R. Spitaler in Prague. He used, however, a different formula to obtain the mean daily radiation, and there are other discrepancies between the two calculation methods. In a recent paper Spitaler (16) has shown that his latest calculations have produced a radiation record essentially similar to that of Milankovitch. This result strengthens the astronomical basis of the theory. The main difference between Milankovitch and Spitaler lies in the amplitudes of some of the maxima and minima.

Much work has been done in the war years on the Continent (17). In Czechoslovakia, Pleistocene geologists have found that the Astronomical Theory is borne out by their field evidence (18).

Radioactivity Chronology. — Two recent developments are of interest.

(*a*) A geological time-scale has been based on the combination of the lead method with the maximum thicknesses of geological systems. Many difficulties have been encountered in the interpretation of lead and helium determinations from radioactive minerals. Professor Holmes (19) therefore selected not more than five age estimates based on the lead method and used them as key points in a new chronology of the geological systems which relies on the world thicknesses of the strata laid down during the successive geological epochs. In the periods which are of interest to the anthropologist, the new scale does not deviate from earlier ones by more than 15 per cent. It has the advantage that it takes into account the geological evidence for the relative durations of the geological epochs. The following tentative estimates may now be accepted for primates allied to the ancestral line of *Homo* :—Anaptomorphidae (primitive tarsioids), 60–55 million years ; *Parapithecus* (catarrhine monkey) and *Propliopithecus*, 35 ; *Proconsul* (anthropoid ape), 25–20 ; *Dryopithecus*, 15–10 million years.

(*b*) Lastly, it should be mentioned that age estimates have been obtained from deep-sea cores, by a method which is different from the usual radioactivity method. The new method measures time within the range of the last 300,000 years, the limit at which the component elements have reached equilibrium (20). The materials required are deep-sea cores of great length. One of these, from the North Atlantic, contained four layers of glacial sediment which, according to Piggot and Urry, were formed between 62,000 and 14,700 years ago. They are regarded as equivalents of the Last Glaciation of North America (21), and there is a chance that such deposits will help us in the establishment of a trans-continental correlation of the Upper Pleistocene and the Postglacial and in answering the question of how long ago the North American continent was first invaded by man.

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Fluorine and the Relative Dating of Bones

By Dr. Kenneth Oakley

THE interest of anthropologists in dating the past is ultimately focused on the dating of the remains of early man. Various geochronological methods have been applied to dating the *deposits* which yield the remains, but methods for the relative dating of bones within a particular deposit would serve a none the less useful purpose from the anthropological point of view.

Many of the most famous finds of fossil man have been marred by doubt as to the genuineness of the observed or inferred association of bones. Boule and others have questioned the association of the Piltdown mandible with the cranial fragments ; Marston has gone so far as to suggest that they may be of different ages. Again, fragments of human skulls of *sapiens*-type were found in apparent association with a Kamasian (' Middle ' Pleistocene) fauna at Kanjera in the Kavirondo region of Victoria Nyanza ; but it has been suggested that the ' association ' was due to disturbance of the beds.

If there were a reliable time-keeping mineral in bones such problems might be solved. Carnot,[1] a French mineralogist, analysed a large number of bones from different geological horizons, and showed that their average fluorine-content increased with geological age. The reason for this is now known to be that bone is partly composed of hydroxy-apatite, a form of calcium phosphate which acts as a trap for wandering fluorine ions, present at least in small numbers in most ground waters. The hydroxy-apatite crystal-units become converted one by one into fluor-apatite, which is a stable mineral, resistant to weathering. For this reason fluorine is not readily leached out after it has been fixed in bone ; and on balance the F-content increases with passage of time. Owing to the porosity of bone the alteration presumably proceeds not zonally but uniformly throughout the body of the material.

Taking the proportion of fluorine to phosphate of lime in fluor-apatite as unity, Carnot showed that the average proportion in bones of increasing age was as follows :

Recent	0·058
Pleistocene . . .	0·360
Late Tertiary . . .	0·595
Early Tertiary. . .	0·645
Mesozoic	0·907
Palaeozoic . . .	0·993

It must be emphasized that these figures are only averages, and that one cannot date a bone by estimating its F-content ; because in one locality fluorine may be abundant in the ground-waters, in another rare. Thus, a Pleistocene bone from a F-rich region may have acquired as much fluorine as a Tertiary bone from a F-poor environment. Nevertheless, if one is dealing with two bones from a particular site, or more reliably two series of bones from a particular region, it should be possible to determine whether they are of the same geological age, or whether one is significantly younger than the other.

The only bones tested from this point of view so far are from a F-rich environment and as might have been predicted from theory, the results are negative but none the less interesting and worthy of record. Dr. L. S. B. Leakey, hearing from me during the Pan-African Congress on Prehistory (1947) about the possibility of such tests, provided for analysis a small parietal fragment belonging to one of the controversial skulls from Kanjera, together with comparative material from the same site, namely : (i) animal bones of undoubted Kamasian age, (ii) a fragment of human parietal of late prehistoric (Wilton) date from a surface deposit. By permission of the Director of the Home Office S. W. Forensic Science Laboratory, Dr. H. J. Walls of that laboratory kindly undertook to test the F-content of these samples. Before proceeding to make accurate determinations, he submitted the samples to preliminary spectrographic tests and these indicated that the F-content of all the bones was approximately of the same order, with the atomic ratio F : Ca in the region of 1 : 5. *This is theoretically the maximum F-content of bone.*

The Kanjera beds contain quantities of volcanic ash and are therefore exceptionally rich in fluorine. The conversion of bone into fluor-apatite evidently proceeds so rapidly in such an environment that no separation of early prehistoric from late prehistoric bones is going to be possible in the case of Kavirondo sites (Kanam and Kanjera). Carnot's results, however, were based on the analysis of bones obtained in Europe mainly from fluorine-deficient environments, thus there is a fair prospect that the relative ages of bones from sites where the F-content of ground-waters is low, as in most of the river terraces of southern England, will be determinable by analysis.

It should be possible to determine for example, whether the Galley Hill skeleton was contemporary with the gravels of the 100 ft. terrace (Thames) in which it was found, or whether, on the other hand, it was a later burial, by comparing its average F-content with that of undoubted fossil bones from those gravels, including the Swanscombe skull. To obtain conclusive proof an elaborate series of carefully controlled and accurate micro-determinations of fluorine would be required ;

[1] A. CARNOT, 1893, *Annals des Mines*, Ser. IX (Mém.), tome iii, p. 155.

but preliminary spectrographic tests would suffice to show the relative abundance of this element in the two sets of bones and would indicate whether a thorough investigation was warranted.

The Piltdown remains might be investigated on the same lines. It has been suggested by Mr. A. T. Marston[1] that the Piltdown mandible (and canine) may not be stratigraphically contemporary with the cranial fragments; that the former is simian and from undisturbed basal gravel, and that the latter belong to *Homo sapiens* and came from an overlaying layer of disturbed gravel of Upper Pleistocene age. Geologists and palaeontologists equally conversant with the evidence do not accept this interpretation of the finds; but Mr. Marston has made a stimulating challenge which might be put to the test by application of the fluorine technique. It is undoubtedly true that the Piltdown gravels contain two groups of animal bones:[2] derived (Red Crag) and contemporary ('Middle' Pleistocene) and it would in any case be instructive to know, through preliminary spectrographic tests at least, whether the F-contents of the bones, animal and human, corresponded in any way to this grouping.

The Principles and Practice of Pollen-analysis

By Dr. H. Godwin, F.R.S.

PRINCIPLES.

(1) *CLIMATIC CONTROL of natural plant communities.* The major drift of climatic change through and since the Ice Age has caused sequences of different vegetation types to occupy the ground. These sequences have been detected and correlated by pollen-analysis.

(2) *PARALLELISM of vegetational development* in different parts of a continent or of a country is a consequence of the controlling climate. Changes are not IDENTICAL but EQUIVALENT therefore in different regions. *Cf.* Ireland, England, Switzerland, Italy

(3) *REVERTENCE in vegetational history* is pronounced feature of post-glacial pollen-diagrams, as especially demonstrated by von Post. The progress from the conditions of the glacial period through to the Postglacial climatic optimum has been continued into a stage of colder climate and reversion of vegetation correspondingly. In the British Isles this revertence is indicated by the diminution of warmth-loving trees such as the linden, and the expansion of less exigeant species, such as the birch.

[1] A. T. MARSTON, 1946. *Geol. Assoc. London, Circular* No. 483, p. 1.

[2] A. T. HOPWOOD, 1935. *Proc. Geol. Assoc. London*, **46**, 47.

PRACTICE :—*Indentification of the pollen of herbaceous plants.*

The most striking alteration of practice in the recent application of pollen-analysis is the greatly increased attention paid to the pollen of herbaceous plants. Greater skill and experience has now permitted us to extend beyond investigation of forest history pure and simple, and two most important vegetational phases are thereby becoming clear (i) the late-glacial and early Postglacial, before the open tundra type vegetation was displaced by the spread of forests, and (ii) the late prehistoric and historic, during which forest clearances for grazing and agriculture have created great stretches of land covered again by herbaceous plants.

MAN AND THE VEGETATIONAL CLIMAX.

Just as climate controlled the natural vegetation types in the early and middle phases of the Postglacial, so the vegetation types have been recognised as dominating the economy of primitive man. Although sound in principle still, it has become evident that not only contemporary primitive man, but prehistoric man has, at least locally, greatly affected the nature of the natural vegetation types. It has been shewn by Iversen in Denmark that in Neolithic times burning and grazing affected local forest composition severely, and the record of this is in the pollen-diagrams. It has similarly become apparent that the great heaths of the 'Breckland' of East Anglia, whose stretches of grass-heath, sand-sedge, heath and bracken have long puzzled ecologists, owed their origin to a breakdown of the overall forest-cover in Neolithic times, a breakdown which it is hard not to associate with the intensive prehistoric occupation of the area in those times, to which the flint mines at Grime's Graves bear witness.

MODIFIED PRINCIPLE :—Interplay of climate, forest history and agriculture.

Gratifying as it is to be able to trace the spread of cultivation by recognition of the pollen of cereals and of weeds of cultivation, it must be recognised that this development modifies the fundamental premise of our methods of analysis, the premise that the recorded communities reflect global climatic change and therefore are subject to parallel movement and revertence. We see the force of this in the view put forward by Iversen that the great increase of birch throughout the British Isles since the opening of the Iron Age must be due to human interference: he bases this upon the fact that the birch is recognised as an easily spread, light-demanding tree

which readily colonised the gaps in the forest made by neolithic man in Denmark.

A close series of pollen analyses at Decoy Pool Wood, on Shapwick Heath, Somerset, has given opportunuty to test this hypothesis. The peat stratigraphy shows two phases of flooding of the sphagnum bogs by base-rich water. The first and most severe flooding was probably the result of the general climatic deterioration at the opening of the Iron Age, the second and slighter flooding is dated to middle or late Romano-British time by the occurrence of late R-B hoards at the bog surface.

The *non-tree* pollen diagram makes it clear that before the first flooding in late Bronze Age times there was some agricultural activity, for there is pollen of *Plantago*, *Artemisia* and of cereals. The flooding, however, brought this phase of agriculture to a close. It was resumed much more actively, however, in the drier period which followed, although the second flooding episode again ended it.

If we now examine the *tree*-pollen diagram it will be evident that the first flooding horizon corresponds with alteration in almost every one of the curves, and these alterations are precisely those typical of the early Iron Age onset elsewhere in Britain. They include the increase of birch and recession of the lime. The rather slight agricultural activity preceding them seems an inadequate cause for such big changes. Moreover at the second and slighter flooding horizon, which terminates a phase of far greater agricultural activity, the course of the tree pollen curves will be seen to have been hardly at all affected.

Forest composition is correlated with the flooding intensity, that is with climate, far more than with the intensity of agriculture, and we may note in passing, that neither the diminution of alder nor of the lime can readily be explained in terms of human exploitation.

It thus appears that whilst in local circumstances the forest composition was temporarily affected by forest clearance by prehistoric man, so that the stages of local recolonisation are evident in the pollen diagrams, where we have to consider the general forest composition of a large area of country, there is as yet no reason to suppose that the effects of the Sub-Alantic climatic degeneration have been wrongly invoked.

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SUB-SECTION K*.—FORESTRY

DEVELOPMENTS IN SCOTTISH FORESTRY

ADDRESS BY

Mr A. H. GOSLING

CHAIRMAN OF THE SUB-SECTION

In this address I want to attempt to review in its proper perspective the present position of Forestry in Scotland and to comment on a few outstanding points both as regards policy and sylvicultural developments and problems.

I think it will be useful first to look backwards. Planting, as we know it to-day, really started in Scotland early in the 18th century. Perhaps the greatest early enthusiast was the then Duke of Argyll, who not only started to plant on quite a considerable scale himself, but also induced some of his friends to follow his example, amongst whom the Duke of Atholl, the Earls of Bute and Loudoun, and Sir Archibald Grant were prominent.

(Before this time almost all the planting done, and certainly all the planting of exotics, was around country houses for amenity purposes, and quite a different technique was employed. In order to get quick results, frequently very large trees were used, 20 feet, 30 feet or even more in height, and the success with which such planting operations were carried out was remarkable.)

The planters of the early 18th century no doubt were also influenced by considerations

of amenity, but the two factors which influenced them more than anything were a growing appreciation of the value of shelter to agriculture and of the fact that extensive planting was a sound financial proposition. The demand for softwoods was growing, and many owners felt there was no better or safer way of providing for their heirs than by planting. A great impetus to their activity was provided about the middle of the century by the importation of the European larch. It rapidly became to be regarded as a much more paying tree to plant than Scots pine and spruce, and extensive areas were planted with it, either pure or in mixture with the older species. This great work of planting by Scottish landowners continued with fluctuating enthusiasm during the first half of the 19th century, but latterly there was a slowing up, and by the end of the century comparatively little extensions of the area under forest were taking place.

During the period which we have so far briefly reviewed, a considerable skill had been developed by Scottish foresters. Their nursery technique, for example, was good by our standards of to-day. The Scottish nursery trade was well established before 1750. The following quotation from Boutcher's work published in 1775 might almost be (if the language was modernised) an extract from a modern book on nursery technique.

> 'From sowing the Fir [i.e. Scots pine] seeds so late in the season as they commonly are they do not appear above ground till the weather is warm and the greatest drought usually begins in the country. Thus they must either be regularly watered (which in large quantities is very expensive) or whole quarters of them may perish in a few days. . . . Neither is this the only misfortune that frequently attends late sowing. There is another and a very great one that never fails and that neither a kindly season nor good soil will prevent, that is the small growth of the plant from which if the succeeding winter is severe the greatest part of them will either be killed or spewed out of the ground. . . . I must here likewise observe an almost universal error in the sowing of seeds which is that if the nurseryman has them not as thick as Cresses he esteems them an insufficient crop. . . . The plants thus raised as thick as they can stand are starved and dwarfish, and from want of air so tender as to be affected and often to perish with the first hard weather.'

So far as sylvicultural practice was concerned, the earlier plantations in Scotland were mainly of Scots pine. In many cases, however, it was mixed with other species such as spruce and also used as a nurse for hardwoods. As previously mentioned the larch assumed popularity soon after its introduction and we find such statements being made as 'there is no soil or situation in which the larch will not far surpass it [i.e. Scots pine] in growth.' Such reckless enthusiasm for larch was neither universal nor long-lived, but there was a general tendency to get away from pure Scots pine. One finds it described as 'the Planter's Forlorn Hope,' as where it fails the case is truly desperate. Planting of mixture of Scots pine, European larch and Norway spruce became very widespread—the idea being that it was a safety first effort to get a more valuable crop than pure Scots pine. Of great importance during the 19th century was the introduction of more exotic conifers—particularly Douglas fir, Sitka spruce and Japanese larch, but, possibly excepting the first named they had not been widely employed before the beginning of the century.

The standard of work and management varied. Some owners planted well and they or their successors suffered the plantations to be neglected later. In many cases, however, there was careful management which resulted in good plantations and financial profit. On such matters as planting distances there was much controversy. Earlier distances were usually about 4 feet or even 5 feet, but continental influence resulted in many reducing this to 3 feet or even less. Planting of 2 × 1 transplants was usual, though in the case of Scots pine the use of seedlings was not exceptional. Thinning practice varied but the general trend as time went on seems to have been to keep the crops dense.

I now propose to pass on to developments of the present century.

The two outstanding points (which are interrelated) are, first, the tremendous devastation of woodlands which occurred during the two world wars, and, secondly, the development of active State interest in Forestry, resulting in the establishment of the Forestry Commission, which has now been given a very large programme of work to carry out. During the first war, felling took place on a quite unprecedented scale. Our forests, which in Scotland were all privately owned, were sacrificed to maintain the national needs of timber. The seriousness of the position was such that the Government appointed a Committee known as the Acland Committee to carry out an exhaustive examination of the situation and to make recommendations. Their recommendations were, in the main, accepted, with the result that the Forestry Commission was appointed in 1919 and embarked on what was then regarded as a large scheme of afforestation. A good start was

made, but the Commission suffered many vicissitudes and its plans and programmes were drastically amended from time to time. Nevertheless, by the outbreak of the second world war it had acquired in Scotland 111 forest units, totalling 546,000 acres of which 274,000 acres were estimated to be plantable and 147,000 acres had actually been planted. By 1939 the planting programme had reached 10,000 acres per annum and was still expanding. A sound organisation had been built up and a great deal had been learnt about the problem of afforestation, and important technical advances achieved. But on the other side of the picture it has to be recorded that fellings continued on a heavy scale after 1918 until the industrial slump, when the home timber trade fell on bad times. Recovery was slow, but throughout the whole period between the two wars the splitting up of private estates and the inevitable felling of timber continued. A portion of the felled areas was replanted by the owners, a small part was acquired by the Commission for replanting, but a large part was allowed to lie unused or subjected to grazing. To encourage clearance of scrub and replanting, the Commission made grants available to private owners. This helped, and about 75 per cent. of the areas so planted proved on a recent assessment to have been satisfactorily maintained. But insufficient progress was made. Felling was in fact going on without adequate replacement. This is not to suggest that owners or the Commission were at fault. Fundamentally the economic and political environments were against good forestry.

Thus in 1939 we had a smaller total area of productive woodland and a very much smaller area of standing timber fit for exploitation than we had in 1914. Yet the extent of the fellings has been even greater in the second war than in the first. Something like two-thirds of the standing timber we had in 1939 has gone. As in 1919 this position has led to Government action : this time it is designed to secure that the woodlands which remain are managed properly, that the felled areas are restocked as quickly as possible, and in turn that they are properly and permanently cared for, and concurrently that the forest area is extended by taking in new land. A scheme known as the Dedication Scheme has been evolved to enable private woodland owners to take a large part in these developments. It would not be appropriate here to discuss the details of the scheme ; I need only draw attention to two points : first, that it does aim to secure that privately owned woodlands shall be *permanently* managed according to a plan approved by the State, and, secondly, that the scale of assistance proposed is much greater than anything hitherto provided. Woods which are not brought under this scheme may be acquired and managed by the State. I think that when our successors are writing the history of Forestry development in Scotland, this event will be one of the most important landmarks. The large extension of the woodland area proposed will inevitably be undertaken mainly by the State. The ultimate object is to get 5,000,000 acres under timber in Great Britain during the next 50 years. Even then we should have only barely 10 per cent. of the country under timber (cf. France 19 per cent., Germany 27 per cent.) and should be producing only about one-third of our present needs. It is estimated we might get two million out of the five million acres from existing woodlands. The balance of three million will come from lands not at present classified as woodlands, in other words largely from rough grazings—probably about 40 per cent. of it will be found in Scotland. The State planting programmes involved in Scotland are approximately 18,000 acres for next year, 24,000 the following year, working up in the seventh year to something like 40,000 acres.

This is a very large task and it remains to be seen whether that rate of expansion will prove attainable.

It is inevitable that the increase in our forest area that is to take place will mean the planting of land which is at present used to some extent for grazing sheep, and this prospect has raised misgivings on the part of some agriculturalists. This is no new development. Writing in 1808 Pontey (Forester to Duke of Bedford) stated :

> ' Some people seem greatly alarmed least the business of planting should be so far extended as to entrench upon agriculture ; the danger however I conceive, lies entirely on the other side for though an old planter I have never known much land devoted to planting that was of considerable value for corn or grass except so far as taking a part to improve the rest by shelter.'

Again, about 40 years later, John Smith (Forester to the Marquis of Bute) wrote :

> ' As already noticed, no ground that the agriculturalist thinks worth improving need be planted except for shelter or ornament and much improvement is still necessary in this way.' He continues, ' It has been argued by some of our great politicians of the present day that it is expedient for a nation to grow its own grain, and I am inclined to believe it is quite as expedient that a nation so far as possible grow its own timber. But there will be ample scope for the ingenuity and skill both of the farmer

and forester for many years ere the ground in Great Britain yields the rental it is, by proper management, capable of.'

I think this well describes the situation to-day. There *is* ample scope for both agriculture and forestry, and if both of these great industries work together in a spirit of co-operation, I do not believe the result will be anything but mutually and nationally beneficial. In Scotland we can claim to have made progress in this co-operation and as the Secretary of State is now responsible for both agriculture and forestry, there is still every facility for co-ordination of effort. It is still true to-day that land should not be taken for forestry if it is worth while improving it for agriculture. But at the same time forestry must not be relegated to the poorest lands which are so unproductive as to be of little value either to agriculture or forestry.

This brings me to another important development in Scottish Forestry to which I wish to refer. During the last 27 years a great deal of investigation has taken place into ways and means of afforesting the poorer peat areas which are so extensive in Scotland. Early efforts such as those started at Borgie and Achnashellach in 1920 were disappointing. Intensive research soon began to throw some light on the problems, and the work which had been carried out on the continent and also by Sir J. Stirling Maxwell at Corrour was most valuable. The importance of drainage and cultivation were quickly recognised. A system of turf planting plus manuring was developed and by 1928 was being applied on a considerable scale with success. Development was, however, limited by expense. On the poorer land, necessary preparation was very costly. Most of it was manual work, horses only being of very limited value. The advent of the caterpillar tractor opened up altogether new possibilities. Special ploughs were designed for the work, and this has enabled us to drain and cultivate more intensively and at a reasonable cost very extensive areas of poor land which earlier we had failed to tackle satisfactorily. Resulting growth is most encouraging. A great deal remains to be done in developing better equipment and techniques. We have still a long way to go. Taking the long view I think this is a most important aspect of our work, as it does show the possible way to the utilisation of much land in Scotland which is at present almost totally unproductive. I have no doubt further progress will be made in this direction and we shall gradually be able to extend our operations on to more of the poorer types. But we must remember, and I emphasise this strongly, that growth on these types will be slower and production less than on better land. What is of prime importance to-day is to get as large an area as we can of fast growing plantation established so that the timber reserve of this country is once again built up to a reasonable level with the minimum possible delay. This cannot be done without utilising better types.

So far as developments of nursery technique are concerned I do not at this stage think it would be appropriate for me to comment, as we are this afternoon to have the unique opportunity of hearing several speakers who are best qualified to deal authoritatively with this vital subject. I would like, however, to refer briefly to one or two sylvicultural developments of recent years. First, choice of species. The fast growing species introduced during the 19th century (Douglas fir, Sitka spruce, Japanese larch) takes a very prominent position in present-day Forestry. About 20 years ago it seemed that Douglas fir was losing popularity and this was chiefly because of poor results from planting on unsuitable sites which arose before sufficient was known of the species requirements. But it is being more widely used again and no doubt this fine species will hold its own. Japanese larch is a newer species about which less is known, but it has already proved of great value. Even if experience later shows that it is not suited for long rotation, it is likely to maintain its position as a short rotation crop. But undoubtedly Sitka spruce is now the most used of these recently introduced conifers. Its rapid growth and high production, the high quality of its thinnings and timber ; its ability to accommodate itself to a wide range of soil conditions ; and its ability to stand exposure make it an invaluable tree in these islands. It is arguable that there is a risk in using this species on a very large scale to the neglect of such a well tried and valuable though slower growing species such as Norway spruce. To guard against this the Commission have in the past aimed at planting at least half of the spruce areas with Norway spruce. Sitka succeeds where Norway will fail on the poorer types of spruce land, and the frequent result has been that Sitka is planted on the poorer spruce sites and Norway on the better sites. But the more we have learned of the Sitka, the more difficult it has become to resist the temptation to use it increasingly. Other exotic species commonly used on a smaller scale include Corsican pine, Tsuga, Thuja, Hybrid larch and *Abies grandis*. On the other hand we can no longer successfully raise the common silver fir of which many fine specimens are still living, nor can we use Weymouth pine. The European larch has steadily declined in popularity (a matter which forms the subject of our meeting to-morrow morning). It is well to recall that the native

Scots pine still plays a prominent part in forestry. About 40 per cent. of the planting done in Scotland by the Forestry Commission is with this species.

The general practice in the early years of the Commission's work was to plant each species pure. The old mixture of Scots pine, Norway spruce and European larch tended to be regarded with some scorn as purely a safety first policy—if the one species did not grow the other might! It was also argued that mixtures were often difficult to control and if the factors of the locality were properly assessed, the best species for each locality could be chosen, and there was nothing to gain by mixture. There has been a notable change in outlook recently. To quote from Sir Roy Robinson's (now Lord Robinson) paper in 1942 on 'Some ecological aspects of afforestation and forestry in Great Britain':

> 'In the natural afforestation of difficult sites some species are pioneers and some are successors. It is not feasible by artificial means to bring in the successors in advance of the pioneers. It is possible, however, to accelerate the natural succession by mixed planting of pioneers and successors and by appropriate thinning treatment to complete the succession in the course of a single rotation. A successor on one site may be a pioneer on another.
>
> 'In the silvicultural treatment of woodlands the most effective methods are those which proceed in the direction of a natural succession of vegetation.'

Perhaps the most frequently used mixture by the Commission in Scotland to-day is Scots pine as the pioneer and Sitka spruce as a successor on the more difficult spruce sites.

We at least have the satisfaction that our mixtures are based on sound scientific theory rather than the hit or miss practice of the early planters.

I have so far said almost nothing about hardwoods. In practically the whole of Scotland hardwoods have never played a a major part in afforestation work, where production rather than amenity or shelter has been the main objective. There has been no change in recent years, unless indeed it has been to emphasise the supremacy of conifers. Most of the land being planted is in fact unsuited to hardwood crops. I think, however, there is need for more study and probably wider use of birch. Mixed Scots pine—birch stands are the natural climax vegetation of large areas in the Highlands. It grows profusely as a weed but we do not know a great deal about the best method of cultivation. A good strain of birch, properly grown, yields valuable timber for which demand is likely to continue. We ought to know more than we do about this common species.

On the subject of planting distances recent, almost universal, practice with conifers has been to use spacing between 4 feet and 5 feet 6 inches, usually 4 feet 6 inches to 5 feet. This is a subject which will always remain controversial, but I do not think there is likely to be any tendency to return to the close spacings of 50 or 100 years ago. At present costs are are high and plants are in short supply. An increase of 3 inches in the spacing from 5 feet to 5 feet 3 inches means a reduction of 10 per cent. in the number of plants required and that is likely to exert some influence which I do not think will be altogether harmful. The recent work in South Africa of J. J. Craib, who advocates spacings in that country as great as 9 feet and 12 feet followed by pruning and early heavy thinning is a most valuable and exhiliarating study of the subject. It is much too soon to say to what extent his theories and practice are applicable to our species in this country, but it is a matter worth careful study and experiments are in hand to test it out. A great deal of evidence has already been accumulated to support the view that much heavier thinnings than were hitherto usual are sound, both sylviculturally and financially.

In his treatise on The Management and Cultivation of Forest Trees published just 100 years ago, John Smith, to whom I have referred earlier wrote:

> 'This is an age of great undertakings; the landed proprietors require but an example, and then intelligence will immediately teach them what a source of gain would accrue from laying all their waste lands under timber.'

To-day these words have even greater application than when they were written. The nation has set out on what is indeed a great forest undertaking. For its success woodland owners will need to take a large part, but we need also the help and encouragement that scientific research can bring to bear.

HOW FAR CAN BRITAIN FEED HERSELF?[1]

By Rt. Hon. Walter Elliot, F.R.S., M.P.

In the United Kingdom a very large population lives on a relatively small area. The essential feature of this large population is that it has arisen almost within living memory—certainly within the last hundred years—and the area in question has never at any time attempted to produce food for anything like the numbers of to-day.

The population of England at the time of Domesday Book was about 1½ millions. To us to-day that seems a tiny figure. Yet it does not differ greatly from the present-day figures of, say, Uruguay in South America, or New Zealand, and each of these countries is approximately of the same area as that of Britain.

The population of England at the time of the Black Death in 1349 was some 3½ millions. By 1680 it had reached some 5½ millions, by the beginning of the 19th century some 10 millions. During all that time Britain was feeding herself. The fact to remember is that Britain has not only continued to feed that number of persons, but has increased her home-maintained population considerably over that figure. The enormous increase of industry, and of the populations founded on industry, during the 19th century brought the population of the Domesday area to 35 millions by the end of the 19th century and to some 40 millions to-day. The aggregate population of the United Kingdom, 47½ millions, represents one of the highest population concentrations in the world.

Even so, we were producing, pre-war, between one-quarter and one-third of the food required—that is to say, for between 11¾ and 15½ million people, a population very much higher than that of any of the Dominions and on a very much smaller area.

During the war this was raised to a figure equal to the food for some 40 per cent. of the population—say 19 million people. This production, had in addition to meet the needs both of the human and of the animal population. The animal population was being maintained pre-war to the extent of at least one-quarter on imported food. The figure mentioned by the Government to-day as a target, though not to be reached before four years, is food for 50 per cent. of the population; that is, for some 23 to 24 million people. This is to be relieved to some extent by an increased import of food for the animal population.

[1] Paper read to Section M (Agriculture) at the Annual Meeting of the Association at Dundee.

Can this figure be reached? Can it be increased? Still more important—must it be increased?

It is first necessary to give consideration to the present performance of British agriculture, as against that of other comparable areas. Future outputs are prophecy, and only prophecy; and, especially in agriculture, prophecy is an unreliable guide. Agriculture in Great Britain is already a larger industry, both in number of persons engaged and in gross output, than that of either New Zealand, Australia, or Canada itself. The actual numbers engaged are (according to figures given by the National Farmers' Union):

Australia . .	470,500
Canada . .	1,244,000
United Kingdom .	1,250,000

From the same source, the gross agricultural output (1943–4), taking comparative cash figures as a standard, is estimated at

Australia . .	£228,000,000 (1943–4)
Canada . .	£562,000,000 (1944)
United Kingdom .	£622,000,000 (1943–4)

The United Kingdom figure was £600,000,000, as estimated for 1945–6, but, even so, was well above the figure for Canada, and, of course, still further above that of Australia.

These comparative figures are difficult to arrive at, and must not be pushed too far; one cannot eat wool and one cannot wear cabbage; they are not interchangeable. But unless some attempt at comparison is made, we are discussing *in vacuo*. The agricultural industry of the United Kingdom is nearly three times as great in numbers of men, and nearly three times as great in gross output, as the agriculture of Australia; and is slightly greater in numbers, and ten per cent. greater in gross output, than the agriculture of Canada. It is safe to say that these figures are not widely known or appreciated.

The British output is all drawn from a cultivated acreage not exceeding 40 million acres or, with an allowance for rough pasturage, say 45 million acres. This area is a mere fraction of one of the provinces of the great states of the New World. The outputs from these British acres far exceed the outputs per acre in the New World generally. These figures of output per acre are more commonly

known, but when we are considering a possible great expansion of production in this country, much of which will have to be drawn from increased efficiency of already cultivated land, they should be borne in mind. Taking wheat as a simple standard of comparison, the average yield in Britain is just under a ton per acre. Production in U.S.A. is just over a third of this figure—between 6 and 7 cwts. per acre—and production in Canada just under a third. That is to say, to step up average grain production in this country, it is necessary to improve upon a figure already three times as high as that of the highly mechanised New World average.

The comparison is fallacious, because these countries are engaged in extensive, low-grade production. It is important to note, however, that British agriculture takes a high place even as compared with the intensively cultivated and laboriously worked acres of Western Europe. Denmark and Holland, the 'garden countries,' have higher wheat yields than ours; the Belgian yield is practically the same as the United Kingdom; France averages slightly over 12 cwts. of wheat to the acre, i.e. only 60 per cent. of the British yield.

Let us look more closely at the figures for Belgium as a country comparable in several respects with our own. The workers per 100 acres in Belgium in 1938 were 13 to 14 against 3 in Great Britain; the overall output per acre (all crops) was £15 as against £7 in Great Britain, which is in the direction one would expect with so great an amount of labour. But the net output per worker in 1938 was £100 in Belgium, as against £200 in Great Britain. The number of persons fed per worker was 9 in Belgium, as against 17 in Great Britain, and the weekly wages per worker (in 1938)—again as one would expect—were 18/- to 22/- in Belgium, as against 30/- to 36/- in Great Britain. Naturally 17 people will pay a man more for feeding them than will nine.

The net output per worker in pounds sterling is another most interesting figure when considering the possibility of an expansion by increased efficiency. The general figures for Great Britain as against the Continental countries were taken out by Yates in 1937 ('Food Production in Western Europe'). They were taken out by Beilby in 1941 for Great Britain as against the New World countries ('Comparative Labour Efficiency in Agriculture,' *Empire Journal of Experimental Agriculture*, April, 1941). Each of the authors again emphasises the fact that these comparisons are approximate rather than exact. Taking Great Britain as £200 per head in 1937 and £205 per head in 1941, the figures for the countries of the Old World were:

	£
Denmark	155
Netherlands	120
Belgium	100
Switzerland	100
France	90
Germany	70

For the countries of the New World the figures were:

	£
New Zealand	450
Australia	300
U.S.A.	185
Canada	135

The high value of output per worker in New Zealand, and to a lesser extent in Australia, is largely due to the very high place which livestock products take in the agriculture of each of these countries. This fact also goes some way to explain the high figure of cash output per head of the agricultural worker in Britain. Since early times, livestock have played a very large, sometimes a predominant, part in British agriculture, to which the Woolsack, the seat of the Lord Chancellor in the House of Lords, testifies to this day.

Any expansion in British agriculture must, to give its greatest benefit, move in harmony with these long established tendencies. When Charles II said: 'There is no climate in the world where a man may be out-of-doors more days with profit than in England,' he was making a statement which holds good, not only for man, but for beast. The temperate well-watered countries of the United Kingdom, with their rain-fall equally distributed over the year, are ideal for stock.

But before an expansion can take place in this field, a great increase will be required to bring us back to where we were pre-war. Our cattle stock has been more or less maintained. Our milch cow population has been slightly increased. But the stocks of sheep have fallen in the most spectacular fashion, and, of course, pigs and poultry have also fallen a great deal.

One set of figures will suffice on sheep. Professor G. M. Trevelyan estimates that the sheep population of England and Wales in 1680 was 10 to 12 millions. In 1939 it was just under 18 millions. In 1942 it was just under 14 millions. In 1945, 12½ millions. The June returns will almost certainly show an all-time low for 250 years—certainly a million, possibly more, below the lowest figures hitherto recorded.

Since it requires between one and two million sheep to bring England up to the level of the seventeenth century, and nearly nine million to bring it up to pre-war, it will

be seen that we have a long way to go to bring the ruminant population to a level where we can make the best use of our grass land. And the ruminant is not only the most efficient processor of grass in existence —it is the greatest labour-saver on the farm. It brings intelligence and even enjoyment to grass-eating as a whole time occupation.

The decline in farm animals which compete more or less directly with man for their sustenance food-stuffs, both home-grown and imported, has been still greater. Again, to take only one figure, England and Wales had 433,000 breeding sows in 1938. The number to-day is 133,000. That is to say, 300,000 more breeding sows would be required to bring England back to pre-war.

The main reason for these great declines is shown in one single figure. United Kingdom imports of animal feeding stuffs between 1934 and 1938 averaged just over 5 million tons per annum, In 1944 they were under a quarter million tons (216,000). They have recovered very little since. Taking the round figure of a ton of grain to equal an acre of arable land (and these tons were better, including as they did large quantities of oil-seed products), the pre-war feeding stuff figure is the equivalent of 5 million acres, upon which British agriculture was previously drawing, cut off since the war. The war-time task of British agriculture was to make good the loss of that 5 million acres ; and roughly speaking, it did so. If this overseas 5 million acres (so to speak) can be restored to British agriculture, expansion in available animal foodstuffs for the people will be well within the bounds of possibility. If not, it may go hard with us.

We are now in a better position to examine the question of actual expansion. The accompanying table supplied from the Ministry of Food shows the total quantities of staple foodstuffs consumed per annum in Great Britain in the years 1934–38 (average), in 1944 and in 1946. There has been, of course, a very great expansion from the pre-war figures. But that is not what we are concerned with. British agriculture must pay regard to the war-time peak as a minimum, not a maximum. Roughly speaking, these figures show that although there was a certain increase in home-produced meat (40,000 tons), fats (13,000 tons), cheese (10 to 12,000 tons), etc., between 1944 and 1946, the supplies derived from home-produced cereals fell enormously—by something like 1½ million tons. Nor is this surprising. The June returns for 1946 show a fall of over a million acres of wheat compared with June, 1944. Barley was up 283,000 acres, but oats were down 69,000 acres. Even the increased supply of home meat in 1946 largely came from the big killing of sheep, cattle, pigs and poultry. It was, in fact, a de-stocking, not a re-stocking.

Food Consumption in the United Kingdom showing the Percentage Home Produced

	Annual Aver. 1934–38		1944		1946	
	Total '000 tons	Per cent. Home Produced	Total '000 tons	Per cent. Home Produced	Total '000 tons	Per cent. Home Produced
Flour from wheat and other cereal products	4,412	13	5,491	42	5,156	28
Fats (butter, lard, margarine)	900	7	819	2	741	4
Sugar (*a*)	2,184	18	1,641	27	1,500	25
Meat (including bacon)	2,712	45	2,838	32	2,305	41
Fish (including canned — edible weight)	562	85	436	55	667	76
Eggs and egg products	500	60	271	64	315	66
Milk (liquid)	4,561	100	6,171	100	6,630	100
Condensed milk	260	70	194	53	163	48
Dried milk	35	61	70	21	52	46
Cheese	185	24	230	7	217	12
Potatoes	3,700	94	6,450	100	6,538	100
Other vegetables	2,260	91	2,721	99	2,541	98
Fruit (including tomatoes)	2,443	26	1,248	62	1,624	47

(*a*) Including sugar for canning, condensed milk and brewing.

All this would normally add up to the conclusion that the production of home-grown food could only be slowly restored to the 1944 peak, and that the increases foreshadowed in the White Paper drawn up by the Minister of Agriculture and the Minister of Food during the war and published in March, 1947 (*Agriculture and the Saving of Foreign Exchange*), would be reached still more slowly, if at all, and this would apply *a fortiori* to the recent proposals for expansion.

But that brings us back to the question

I ventured to put at the beginning of this paper. Must it be increased? And how rapidly?

I think the answer, the inescapable answer, is—'It must' and 'Now.' The reasons for that are two-fold.

First of all, the very acute short-term position. Second, the equally menacing 'mid-term' position. I do not discuss the 'long-term' position because the factors are so many and so unknown as to be incalculable. The sky might fall, in which case we should catch a great many larks. Or we might return to the nineteenth century—in which case we should have multilateral free trade. Each event is about as likely as the other, and as fantastic. Our business is with immediate possibilities. The short term position is, as we all know, that world food is short, and international cash, legal tender, is shorter still. Food is even shorter than it seems, because in the middle of 1943 (as has been pointed out by Mr. J. E. Wall (*International Affairs*, 1947), the total stocks of wheat in the four exporting countries of the world were about 46 million tons, and by the middle of 1946 had fallen to 12 million tons. That is to say, the world in these three years drew 34 million tons of wheat alone from stock, and a similar movement has taken place in all the major foods. The world grain reserves rose between July, 1946 and July, 1947, by nearly 20 per cent., but almost the whole of this rise is accounted for by last year's record maize crop in the United States. The current failure of this year's crop will more than wipe out the carry-over, and wheat from the winter harvest will be used to make up the difference. Indeed, the whole world is at present dangerously dependent on a continuation of good North American harvests. We have all seen one American drought in recent years. A similar drought could reduce supplies by something of the order of 8 to 10 million tons in a single year—the total of the 1946 stocks of all four exporting countries.

As to the shortage of cash there is no need to speak. The only thing to say is that the words 'dollar crisis' seem inappropriate. When we see the sun sloping across the sky all day from east to west, reaching the horizon and finally going below it, the coming of night can scarcely be called a crisis. The fact that it was going to be very difficult to find something that we had to spare, that the Americans wanted, and that the Americans could not make for themselves, was just as obvious as the coming of sunset. It will be very remarkable if the run of American bumper harvests continues. It will be miraculous if we find ourselves with sufficient spare goods, of a kind wanted in America, to purchase these harvests.

But it is in the mid-term position that the danger really lies. In Asia the ghost of an old Church of England clergyman called Malthus has recently risen from the grave and is stalking the land. The deputy-leader of the Indian Delegation at the Food and Agriculture Organisation Preparatory Commission in Washington told his hearers that 25 to 30 years ago the average Indian consumer received 2,500 calories a day. In the last 15 years he has been getting much less. The reason is that the population increase has outrun the expansion of production. The story is the same throughout the East. The F.A.O. Conference now meeting in Geneva has an estimate of world-population increase—mostly in the East—of 400,000,000 in the next generation, a figure equal to the present population of India—mouths to fill for whom no present provision is made at all. It was stated in World Food Survey (F.A.O.) that for cereals alone, India and China would require by 1960—13 years hence—to bring them up to a satisfactory health standard, 38 million tons a year *more* than at present. This figure represents the total *production*, pre-war, of the U.S.A., Canada, Australia and Argentine put together. It had taken these more countries than 13 years to work up to that.

Whether these figures can ever be achieved is a matter of opinion. But it would clearly be in the highest degree imprudent to count on a rapid and permanent resumption of large scale bulk exports of food from the Eastern hemisphere. This also makes one doubtful about the prospects of great new food supplies from Africa. However rapid the development—and great developments, such as irrigation, have been going steadily forward in India—the pressure of population upon food has proved in many cases more rapid still.

It appears, therefore, that the expansion of food production in this country is a 'must,' and a 'must' by no means limited to the provision of 50 per cent. of our rations (which means overseas food for every second person, from year's end to year's end)—as envisaged by the Government plan. The chief factor still apparently lacking is a sense of urgency. The petition for daily bread is the first of all the petitions.

How far Britain can feed herself depends first of all, therefore, on how much effort she is willing to put forth to ward off hunger. All one can say with certainty is that she can assuredly feed from 30 to 40 per cent. of her population, because she has done it. How far she can go beyond that depends on (1) increased labour supply and labour output,

(2) increased efficiency in producing plant life and animal life dependent on it, (3) increased good-will from countries overseas in the provision of balancer supplies, (4) the proportion which Britain chooses to strike between the consumption of animal and plant products respectively, (5) the imponderables, weather, disease, etc. These take on a continually increased importance in proportion to the rate at which the soil is driven. Narrowing the margin of safety is another way of living on stocks.

Hunger is certainly not very far off. In the debate on Food Supplies, July 1, 1947, the Minister of Food said that the average number of calories consumed per head per day in this country was between 2,880 and 2,890. This consumption figure is queried by Professor Marrack, who considers that the total actually consumed does not run to much more than 2,650. In the publication *Food Consumption Levels in the U.S.A., Canada and the United Kingdom* it is stated that an over-all supply level of 2,800 calories is necessary if the intake ' off the plate ' is to be of the order of 2,500 calories per day. This document also says that an over-all intake of 2,700 when reached in Great Britain during the war began to produce a loss of body-weight—that is to say, to draw on the last reserves, the flesh and blood of the people. How near that point the further reductions in food purchases overseas, recently announced by the Government, will bring us, I do not know. But at the point of the loss of body-weight you reach hunger.

In practically all of the factors enumerated the actual prices proposed for the goods—the financial terms of the contract—are not the last word. The last word lies with the physical resources about to be made available. In any campaign it is necessary that the troops should be promptly and adequately paid. But the artillery support, the air co-operation, the efficiency of the supply services, count for much more when the actual crunch begins.

On (1), housing and rural transport are crucial as far as supply of labour is concerned. On utilisation of labour, mechanisation is the key-factor. Already we have 180,000 tractors on British farms, equivalent to 1,800,000 h.p. One machinery horse-power is equal to the average work of 20 men and, assuming only 50% use of this machinery, this is equivalent to the work of 18 million " steel men." In passing, and with relation to the efficiency of agriculture, it may be mentioned that the number of tractors in March, 1918, was under 3,000. In 1939 it was 55,000. The progress between 1918 and the present day would compare favourably with that of any other industry. It is clear that the efficiency of the 1¼ million human beings will be largely conditioned by that of the 18 million " steel men " whom they command. I should have liked to see, with the announcement of the agricultural production plan, the announcement of an Industrial Supply Department with the same powers of top priority and acceleration that Lord Beaverbrook had during the initial stages of the Ministry of Aircraft production.

On (2), increased efficiency, very careful consideration will have to be given to the comparative figures for the other agricultures just quoted. The soil of this country is going to be driven as never before, and may be without the added extracts from soils abroad which the massive imports of animal feeding stuffs represented. This is all the more important, since the whole of the residues from animal feeding-stuffs were returned directly to the soil in the form of animal manure, whereas the whole of the residue from human food is in general cast away in the form of sewage. The remarks of our President, Dr. Ogg, on ' Soils and Health ' are of very great importance. The ' trace ' elements, and trace factors generally, are, in high pressure conditions, of vital significance. We are bound to replace by direct supply the heavy drain on our soils of lime and phosphate. In supplying these, we may be omitting other factors and elements of equal importance. Our knowledge of and our experimental attack upon this problem lag far behind the urgencies of to-day and the necessities of to-morrow. Improving the breeds of animals and plants must take a second place to this fundamental process of providing and maintaining a healthy soil. The feed must be above the breed, for plants as for animals.

On point (3), increased good-will from countries overseas, this must turn largely on increased co-operation, first, between Great Britain and the Dominions, and next between Great Britain and Western Europe and the U.S.A. Chiefly with Britain and the Dominions. For others it is a question of business. For the Commonwealth, it is a question of survival.

On point (4), the balance between animal and plant products, this largely depends on the amount of animal feeding-stuffs which can be brought from overseas. Ton for ton, this island can in general produce more food in grass than in any other ways. But human beings cannot eat grass, and if feeding-stuffs cannot be imported, the plough must go through the sward, however good it is. On the point (5), the last, the imponderables, their importance largely depends on the pressure under which the whole scheme is working. This is a familiar factor in machinery. It is not always recognised that it also

holds good for living processes. The highly productive laying hen, the deep-milking cow are examples of liability to breakdown with which we are all familiar. We remember also, how, a hundred years ago, the monoculture of potatoes in Ireland broke down with disastrous consequences. To drive all the soil and all the animals in the United Kingdom at top speed is feasible. But then, an unpredictable virus disease, an invasion by a new insect pest, or even a wet harvest might bring disaster here also.

To sum up, Britain has reached a pass at which effort must be expended, even to the point of diminishing returns, and many risks taken. To feed one-third of our population can easily be done and well done. To feed a half of our population can be done, but will require both effort and organising ability on a scale greater than has yet been evinced. To feed two-thirds, or even three-quarters, might be within the bounds of possibility; but it would require siege conditions, both in diet and in conditions of work. I do not think that under any circumstances Britain could maintain her whole present population from her own soil at a full standard of living. As the scale rises, the pressure towards the other solution, of bringing the people to new and wider grounds—emigration, would become increasingly attractive. And this, if present tensions do not relax, will certainly have to take its place as one of the practical alternatives.

HUMAN EFFICIENCY AS AFFECTED BY CLIMATE AND ITS RELATION TO SOCIAL DEVELOPMENT[1]

By

Prof. H. C. BAZETT, C.B.E.

Climate plays, and has always played, an important rôle in determining man's history. It exerts direct effects on his health, physiological efficiency and psychology. In addition, it produces indirect effects by influencing his food supply and in other ways modifying his economy. All these factors will be considered in this symposium, but I intend to limit myself to questions of health and efficiency; in so doing I will have to give some consideration to the interrelations of physiology and psychology.

Much has been written and published in the past in attempts to analyse history so as to elucidate these effects of climate. I mention the large and learned volumes of Ellsworth Huntington and A. J. Toynbee, and the shorter and more popular books of C. A. Mills and S. F. Markham. They all agree that the whole development of man has been immensely affected by both climate and housing developments. In houses an artificial environment is set up, in which heat and light are controlled, so that man can provide his own environment, and can make it superior to any natural climate. The effects of the provision of artificial light and heat within houses may be traced in man's development during periods that exceed recorded history. There is no need to turn to history to learn the ill effects of interference with the supply of adequate light and heat. These are unfortunately only too familiar.

During the present century a new situation has arisen. It is now possible to cool buildings on a large scale as well as to heat them, and the humidity of the air may also be controlled. Air-conditioning of houses in the tropics consequently becomes theoretically possible. Conditions which are optimal for man can now be provided in the tropics by the use of cold just as they have been previously provided in cold areas by the use of heat. This new technical procedure is still an infant; it has only influenced mankind for a few years and it has as yet not attained its full efficiency. Its importance in future years is hard to estimate.

The authors I have cited, while in complete agreement on the dominant effect of climate and housing techniques on the development of civilisation, unfortunately disagree violently in their analyses as to what is cause and what effect. Even when several of them agree, the conclusions reached may be based on entirely wrong scientific concepts! Yet no large-scale plans, commensurate with the importance of the subject, have yet been made to study this field by the experimental method. There is no valid reason why the experimental method should not be used, except that of expense. The atomic energy

[1] Read before Section I (Physiology) on Sept. 1, 1947 (in a Symposium on Climate and Health), at the Dundee Meeting of the British Association.

experiments have now taught us that experiments, which involve immense expense, may not only prove useful, but may also give promise of ultimate financial profit. I would plead therefore for a comprehensive study of the effects of climate on man which would utilise both observations of existing conditions and the experimental modification of these conditions, and which would be international in scope.

During the war a considerable amount of work was carried out in attempts to protect the troops from injurious effects of climate. Considerable improvements were attained in the protection of an individual against cold, a problem which received much attention because it affected all three services—the Air Force as the result of the very low temperatures experienced at altitudes, the Navy owing to conditions such as those of the Murmansk run, and the Army in its bitter experience of wet cold in Italy. The ill effects of heat were also seen in the tropics, but much less success was attained in overcoming them. In spite of this I intend to confine most of my attention to tropical problems, since I believe the solution of these problems to be of immense importance to the peace-time economy of the world.

The ill effects of heat were demonstrated on shipboard during the war. A naval vessel blacked out and closed down for action in the tropics, attained temperatures 10° F. or more above that of the external tropical environment and also developed high humidities. The effect of human efficiency was often serious. In the early years of the war these bad effects were particularly in evidence in British submarines in the tropics, and it is probable that some of these ships were lost as the result of high temperatures alone, and independent of direct enemy action. The crews of British submarines in the tropics had at first the unenviable record of being the least healthy of the whole Eastern Fleet and as having the lowest morale. American submarines fitted with air-conditioning units had no such record. Later the Admiralty had air-conditioning installed in all British submarines assigned to tropical service; at once the crews changed to become the most healthy of the whole fleet, and also those with the highest possible morale. It seemed therefore likely that all the other vessels of the fleet in the tropics were working at a subnormal efficiency due to high temperatures, and steps were undertaken to investigate this situation.

The effect of excessive heat on man's efficency still remains of immense importance, even though the war be ended. If men in the services lost efficiency as the result of exposure for a few months or years, it is improbable that the climate is without effect on the native population, who are exposed to them for generations. Air-conditioning is spreading and must inevitably ultimately attain widespread use in the tropics. It is steadily becoming less expensive and more efficient and is already being utilised in some factories where native labour is employed, because of its beneficial effect on production. Its utilisation is bound to modify the conditions of life, and, secondarily, the character of the native populations exposed to it, though many mistakes will be made costing much money, time and energy, and producing confusion instead of efficiency. If the subject was investigated experimentally and systematically much of this waste might be avoided. It is inconceivable that any such systematic study, however great the initial expense might be, could be less efficient than the hit or miss method of gradual industrial expansion in the use of such equipment without co-ordinated research work.

Man would appear to have evolved originally in a tropical or subtropical climate. Early civilisations, such as those of Ur, Egypt and of North India, arose in subtropical conditions. History records the drift of the centre of civilisation ever more and more towards the cooler areas of the globe. According to Markham, this movement has depended on the development of technical methods of heating. Recently, the spread of organised civilisation into the extremely cold areas of northern Canada and of Russia has been conspicuous. These developments have been rendered economically possible by the utilisation of electric lighting and central heating. Even so, adequate economy could not be attained readily without the employment of large well-insulated buildings with relatively few outside walls, such as the workmen's apartment buildings in Russia.

The whole mode of development of the world is changing. No longer does the evolution of man depend on the survival of the fittest, on the basis of pure chance. Man becomes master of his own evolution. Evolution now depends on the survival of those who make themselves the fittest. It therefore becomes our duty to plan our own evolution on a basis of sanity. War and cut-throat competition should no longer be our accepted methods of evolution. Rather, friendly competition, such as we scientists know and value, should be utilised to develop an economy adaptable to all mankind. It is the relation of climate, and control of climate, to such distant ideals, that I would have you bear in mind, while considering more prosaic details.

The effect of climate on health may be demonstrated to some extent by utilising available statistical data on the monthly incidence of diseases. Indications so derived may be particularly striking in climates which

show extreme variations in temperature, of the type common in most parts of the United States. Cardiovascular diseases may be used as an example. Such diseases in old people are commonly associated with high blood pressure, and they are responsible for a high proportion of deaths, often dependent on cardiac failure, coronary disease or cerebral hæmorrhage. All of these complications show seasonal variations in incidence, which appear dependent on failure of physiological adjustments rather than on mere chance infections.

The records of monthly incidence of cardiac failure in this type of patient in Philadelphia for 1936 shows that the minimal monthly incidences are seen in the hottest months of the summer and the coldest months of the winter. Maximal incidence accompanies the rapidly changing conditions of the spring and autumn.

in volume, since blood pooled in the feet is partially removed from circulation. This is indicated in Table I. The body reacts to this effective decrease by producing more plasma protein which aids absorption of fluid and gradually returns the reduced volume towards normal. The sequence of the changes depends (1) on a rapid loss of fluid filtered from the blood, (2) a gradual return of some of this fluid during a reaction, as colloid osmotic pressures are intensified by formation of additional plasma protein, and (3) on the absence of change in the absolute volume of red cells, since the changes in this volume are only produced slowly.

On lying down, the opposite changes occur, namely, a return to active circulation of blood previously pooled in the legs, and absorption of tissue fluid from the dependent parts into

TABLE I.—CHANGE IN BLOOD VOLUME AND BLOOD VISCOSITY

Conditions	Real Volume	*Initial State*		*Reactions*	
		Effective Volume	Viscosity	Volume	Viscosity
Posture					
Standing .	−	− −	+	Less −	towards normal
Lying .	+	+ +	−	Less +	towards normal
Change of Temperature					
Heat . .	+	−	−	+ +	− − then to normal
Cold . .	−	+	+	− −	+ + then to normal

The possible reasons which link climatic changes with exacerbations of cardiovascular disease must be examined, even though this can only be done on a basis of pure hypothesis. Certain facts are known which might account for the observed phenomena, but at present there is no direct proof of such relations. Considering, first, cardiac failure, this condition is accompanied commonly by a large increase in blood volume. This is probably an exaggeration of a smaller change seen in normal subjects with change in posture. When a normal individual stands, blood collects in the lower limbs from the effects of gravity, and fluid also leaves the blood and passes into the tissues. The absolute volume of the blood is reduced by the loss of fluid. The viscosity of the blood is also increased by the resulting concentration of the red blood, corpuscles. The effective decrease in blood volume is much greater than the real change

the blood, with a consequent increase in blood volume. The reaction to this is a removal of excess plasma protein, which allows the blood volume again gradually to be reduced. These changes, described in principle by Starling, have been recently demonstrated experimentally by C. R. Spealman in my laboratory. The changes accompanying the onset of cardiac decompensation appear to be an exaggeration of the increase in plasma protein in the erect position with a consequent grossly enlarged blood volume on the reassumption of the recumbent posture and reabsorption of excess tissue fluid. This point of view is that recently developed by Landis *et al.* (1946). The over-distension of the heart resulting from these changes precipitates cardiac failure.

The effects produced by sudden changes in temperature in many respects resemble those due to postural changes and may reinforce them. Thus the blood volume is increased

in reaction to heat, as was first demonstrated by the late Sir Joseph Barcroft. The dilatation of the large veins necessitates an increase in blood volume to fill them. Initially the effective blood volume is inadequate and the veins are filled at a subnormal pressure unless compensation is attained by vasoconstriction elsewhere. On return to cold conditions the enlarged blood volume exceeds that which is needed and may exaggerate the normal excess accompanying the initial stages of recumbency. Such additive effects may help to precipitate cardiac failure. The reduction of blood volume in response to cooling following prolonged exposure to heat is accompanied also by a temporary increased protein concentration in the plasma and an abnormally high haemotocrit. The consequent increase in viscosity might influence the circulation in abnormal coronary vessels adversely, particularly if combined with the similar change induced by standing. Careful observation and analysis of the adjustments of elderly people to rapid changes in temperature are needed to determine the validity of such assumptions. The possible additive effects of thermal and postural reactions are indicated in Table I.

Evidence of the changes in blood volume in young subjects in the spring has been described by Maxfield *et al.* (1941). One might expect that the ill-effects of cold in elderly subjects might be due to an exaggeration of high blood pressures in response to cold. However, as judged by experiments on normal subjects, this does not appear to be the case. Any initial use of pressure in reaction to cold does not appear to be maintained in continued exposure to moderate cold. In intermediate stages of acclimatisation the blood pressure is, on the contrary, lowered, and remains low until the later stages of acclimatisation to cold are attained (Scott *et al.* 1939).

If conditions existing in the spring and autumn in stormy climates set up stresses which are hard on old people, even greater stresses are to be anticipated when individuals move by air from one extreme climate to another. It is possible now to move from the tropical heat of a climate just south of the equator to the severity of a northern midwinter within a single day. People subjected to such stresses are also particularly likely both to be old and to occupy positions of high authority, since such people can afford air travel more commonly than others and also may be forced by circumstances to travel as rapidly as possible. Study to allow protection of people of this type is badly needed. I would not wish to imply for a moment that blood volume changes are involved in such stresses. It would, however, be convenient if it were so. The blood volume can be altered more or less at will by the physician by the simple processes of bleeding and transfusion. Consequently, if changes in blood volume were indeed concerned, the problem of prevention might be solved.

The stresses resulting from air travel are only a minor factor in the effects of climate on the ill health of the world. Temporary residence in, or travel through, the tropics is apt to spread tropical diseases, which can only be eradicated by greatly improved sanitation; the spread of such diseases may prove serious. Yet the tropical areas contain a large proportion of the undeveloped wealth of the world, and both travel through, and temporary residence in, the tropics is likely to increase. Improvement in the local sanitation can only be attained when the local population acquires a high educational level. This in turn is probably unobtainable in the worst climates, unless the temperature conditions for ordinary life can be ameliorated.

The average child, whether white or coloured, cannot be expected to study well, either in school or at home, under unduly hot conditions. In a bamboo hut, with no windows and only blinds to exclude insects, maintained at a temperature which results in persistent sweating, there is little inclination to do mental work. Not only is education difficult but deterioration is apt to be observed even in well-educated white adults. Nor are the natives entirely immune to such effects. Their energy and initiative are reduced. For adequate development of the worst areas, drastic changes in the present housing situation are required.

Even the effects of moderate differences in climate may be recognised if they last for generations, for the effects seem to accumulate. I quote A. J. Toynbee for a description of the differences between the northern Scot and the southern Englishman. He writes: 'There is no need to argue the point that Scotland is a "harder" land than England, nor to elaborate the notorious differences of temperament between the traditional Scotsman—solemn, parsimonious, persistent, cautious, conscientious and well-educated—and the traditional Englishman—frivolous, extravagant, vague, spasmodic, careless, free and easy, and ill-grounded in book-learning.' One cannot deny that there is some basis for such statements, though if the differences depend on climate, they are no sufficient reason for pride. If the Scots could exchange climates with their more southern cousins the Cornishmen for a few generations, they might become even as 'frivolous' as are the Cornishmen.

Whatever may be the causes of these effects of climate, they cannot depend on

mere racial strains. The same types of difference are to be found between the north and south of France, the northern and southern States of America, northern and southern Italians, or northern and southern inhabitants of India. Neither can the effects be ascribed with certainty entirely to the direct effects of climate on the growing individual, for it is believed that some of the characteristics of the parent stock may be retained, even when the family is moved to another climate. Yet there is no justification for assuming any modification of the genes. Any transmitted effect would appear, therefore, to be due to some ill-defined effect, possibly of psychological origin, such as the influence of the parents on the children, though I must admit that any such influence is difficult to accept as an active force in the present age.

A discussion of air-conditioning of the tropics may appear to be academic, as it seems to be unrealistic and entirely impossible of attainment. Particularly is this the case when one considers that much of the wealth of tropical areas is agricultural, and consideration of air-conditioning of the environment of agricultural workers while at work must be accepted as at present quite ridiculous. However, it is incorrect to consider the procedure out of court. Most thoughtful observers in the tropics consider the control of conditions in the bedrooms much more important than that of the workshop. Some years ago individual cooling units were issued to the staff in the Iranian oil fields. At first some installed these units in the living-room and some in the bedroom, but the experience of a very few weeks resulted in them all being moved to the bedrooms. It is probable that the output of factory workers in a tropical environment would be increased more by cooling their living quarters than by cooling the factories. The main difficulty is that greater changes would be required in the accustomed mode of life. Again the degree of cooling needed is small. Probably the rooms should be somewhat dehumidified, but only be cooled to 80° F. (27° C.) or at most to 78° F. (26° C.). This would imply setting up a differential between the inside and outside of only some 10° to 15° F. as compared with differentials of 50° to 70° F., that are often maintained in cold climates.

However this may be, it seems certain that large-scale air-conditioning of houses in tropical areas cannot be attained economically without a complete change in the character of the houses. To obtain cooling it will be essential to replace light bamboo structures with stone houses or other buildings with well-insulated walls. The buildings must also be large so as to have a relatively small proportion of outside walls ; apartment buildings of a type similar to those used in Canada or in Russia to keep out cold will be needed.

Nothing is known as to the ideal climate, for it is not even possible as yet to decide what are the factors which influence the development of civilisation. Three of the authors analysing history, who have been cited, believe that hard conditions act as a stimulus, as a challenge, while soft conditions lead to stagnation and degeneration. You may have noticed that Toynbee ascribed the high qualities of the Scot to the hardness of the climate. These same authors ascribe the stimulating effects of changeable climates to rapid alterations in barometric pressure. Yet there is not one iota of scientific evidence to suggest that pressure changes of such small magnitude have *per se* any effect whatever on the physiological processes of man. In contrast to these authors Markham attributes the growth of civilisation to technical advances in housing, and the consequent provision indoors of an artificial climate more suitable for growth than any natural climate. In his view ' soft ' indoor conditions have exerted a favourable influence.

Quite possibly both points of view are partly right. The beneficial effect of good housing with warm rooms and good lighting in a cold climate may depend on contrast. Possibly the effect is mainly psychological. It is undeniable that a nice fire and a good light are a temptation to indulge in reading and writing, particularly when the outside world is ' cold and dark and dreary, it rains and the wind is never weary.' On such an hypothesis the same stimulus both to theoretical study and to indoor crafts might be obtained by a cool dehumidified room existing in a hot humid tropical climate, and ultimately the pleasant character of such conditions might also lead to their own poetical eulogy. The high educational level in Scotland might then depend not so much on good housing, as on the abominable weather that may often be found outside it.

In any case the criticism of the overemphasis of the value of technical aids, which is voiced by Toynbee, is probably not intended to be applied to the consideration of technics involved in housing. It certainly should not be so applied. It would be impossible to imagine a modern civilisation flourishing in northern areas if the housing were limited to igloo huts or in the tropics if huts of bamboo construction were alone available. For the proper use of schools, scientific laboratories, rooms for mechanical drawing, shops for lathe or similar machine work, etc., all of which are essential both for education and industry, centrally heated buildings are needed in cold climates, and air-conditioned buildings are equally essential in the tropics.

Austerity may be good for character but in Britain it is realised that over-cold rooms and inadequate supply of electric power for light do not promote the growth of civilisation, nor aid in the education of children. Similarly in the United States in the present absence of air-conditioning in the schools, it is recognised that it would be inefficient to force the children to attend school throughout the intense heat of the summer.

I would like to see an experiment started on a grand scale and organised to continue for at least 20 to 50 years. In such an experiment two tropical villages, preferably agricultural, should be selected with at least some 200 inhabitants in each. In both, adequate nutrition, sanitation, and educational facilities should be guaranteed (by subsidy if necessary) so that the populations would not be tempted to migrate. One such idealised village should act as a control and should retain its present type of housing, though provided under the best possible conditions. The other village should be experimental and should differ from the first only in the replacement of its houses by large well-insulated buildings of an apartment type, and the whole should be fully air-conditioned.

Studies should be made on the intelligence, initiative and health of the two communities ; particular stress should be laid on the comparative rates of breeding in the two communities, since a too rapid growth of the population creates many of the problems of a tropical community. No conclusions should be drawn until children had been born and grown to manhood in these environments, until the records of several generations had at least begun to accumulate.

Many countries could serve for such an experiment, but I should like it tried in India. India teems with a population which is rapidly expanding, and continually outgrows its resources. She has a proud history. In spite of a very difficult climate she has racial stocks of proven high intellectual capacity. Without the development of large industries and the use of more scientific methods in agriculture, she cannot hope to support her rapidly growing population. If air-conditioning of homes can be more effective than that of factories she needs to know it, for such a change would require a revolution in her normal customs. India, one of the birthplaces of civilisation, has suffered in competition in the absence of technical skills for the control of hot climates. Now that these technics have been made available, who can tell what future may lie before her ?

It is true that India's primary lack at present is adequate food, and also that much of India has no source of power to supply such widespread cooling equipment. Large-scale air-conditioning for the present is entirely impracticable. However, these difficulties do not prevent the limited experiment being made. The experiment itself can give no certain answer at least for 20 years. Must we be so pessimistic as to assume that the provision of food will be as acute a problem in 20 years' time as it is to-day ? Can we really predict that adequate power will not be available in India in 20 years' time, particularly in these days of exploitation of atomic energy ? This is no time to refuse to explore possible avenues of progress, no time to neglect to accumulate information, which does not seem obtainable in unequivocable form from historical records.

We are at a stage in history where we must plan our own evolution. We should do this with more thought than we are now giving to it. In planning our own evolution we should make experiments to test theories as to the factors which affect us, so that we may not go to work on a basis of false premises. Experiments in such a field cannot be made by any one person ; they cannot even be completed in any one man's life-time. They demand systems of committee control and team work beyond any as yet attained. The results of the experiments should be available to the whole world, so that international co-operation should be enlisted even in the initial plans. One such world problem is that introduced by air-conditioning which is likely to affect the growth of civilisation immensely, and may do so to an extent comparable to the effect of the discovery of fire. In any case, air-conditioning is apt to cause the centres of civilisation to shift back towards the warmer areas of the world, reversing the present northward drift. Consequently, the British Association and other similar scientific bodies should give thought to the guidance of these inevitable trends.

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DUNDEE MEETING : 1947

SECTIONAL TRANSACTIONS

SECTION A

MATHEMATICS AND PHYSICS

August 28

DISCUSSION on *Peace-time applications of nuclear fission.*

Prof. J. D. Cockcroft, C.B.E., F.R.S.—*Introduction.*

Dr. O. R. Frisch.—*The fission pile as a research instrument.*

Mr. W. G. Marley.—*The production of radioactive isotopes.*

August 29

DISCUSSION on *Radio applications in astronomy and meteorology.*

PRESIDENTIAL ADDRESS by Sir Edward Appleton, G.B.E., K.C.B., F.R.S., on *Earth, stars and radio.*

Dr. E. G. Dymond.—*Radiosonde.*

Mr. H. L. Wright.—*Application of radio to upper wind measurement.*

Dr. R. L. Smith-Rose.—*Location of thunderstorms.*

Mr. J. S. Hey.—*Astronomical applications.*

Dr. A. B. Lovell.—*Meteors.*

Mr. M. Ryle.—*Radio frequency radiation from the sun.*

Mr. H. G. Booker.—*Propagation of centimetre and metre wavelengths in the troposphere.*

September 1

DISCUSSION on *Modern methods of computation.*

Dr. J. C. P. Miller.—*General survey of computational methods.*

Mr. J. H. Wilkinson.—*Some modern large scale digital computing machines.*

Dr. L. Fox.—*Relaxation methods.*

Dr. J. M. Jackson.—*An electronic differential analyser.*

Prof. M. Born, F.R.S.—*Fourier transformer.*

September 2

DISCUSSION on *Coal as a source of heat and power.*

Prof. H. L. Riley.—*The physics of coal combustion.*

Dr. A. C. Monkhouse.—*The efficient use of fuel.*

Mr. A. T. Pickles.—*Domestic heating systems.*

Prof. J. D. Bernal, F.R.S.—*Coal economy in domestic heating.*

Dr. D. H. Bangham.—*The combustion of coal in fuel beds.*

Miss M. V. Griffiths.—*Domestic fuel economy from the electrical aspect.*

Mr. M. W. Thring.—*The reduction of energy requirements for steelmaking.*

September 3

DISCUSSION on *Infra-red radiations and their applications.*

Dr. E. Lee.—*The infra-red image converter in war and peace.*

Mr. T. H. Pratt.—*Photo-conductivity in the infra-red region.*

Dr. G. B. B. M. Sutherland.—*Infra-red spectroscopy and new materials and detectors.*

Dr. G. F. J. Garlick.—*Infra-red sensitive phosphors.*

Mr. G. A. Jones.—*Infra-red sensitive emulsions and applications.*

SUB-SECTION A*

MATHEMATICS

August 28

Prof. E. T. Copson.—*The equation of wave motions and its generalisations.*

September 2

Prof. H. M. MacNeille.—*Integration.*

Mr. G. Owen.—*Genetical recombination as a stochastic process.*

September 3

Dr. B. H. Neumann.—*Convexity in elementary geometry.*

Dr. V. C. A. Ferraro.—*Non linear mechanics.*

SECTION B

CHEMISTRY

August 28

PRESIDENTIAL ADDRESS by Dr. J. L. Simonsen, F.R.S., on *Science and the Colonies.*

JOINT DISCUSSION with Sections D (Zoology) and M (Agriculture) on *Insecticides.*

Chairman : Dr. J. L. Simonsen, F.R.S.

Mr. C. T. Gimingham, O.B.E.—*The place of insecticides in agriculture.*

Prof. J. W. Munro.—*The place of insecticides in food protection.*

Dr. J. L. Gunn.—*Experiments with aircraft in the control of locusts and other insects.*

Dr. C. Potter.—*Biological problems in the study of insecticides.*

Dr. V. B. Wigglesworth, F.R.S.—*The contribution of insect physiology to the study of insecticides.*

August 29

JOINT DISCUSSION with Sections I (Physiology) and K (Botany) on *Penicillin and other antibiotics.* (*See entry under Section I.*)

September 1

DISCUSSION on *Chemical resources and industries of Scotland.*

Chairman : Dr. J. L. Simonsen, F.R.S.

Mr. T. H. Whitehead, F.R.S.E.—*Mineral resources.*

Mr. R. H. S. Robertson.—*Some principles of raw material development.*

Mr. A. G. E. Robiette.—*Hydro-electric power utilisation.*

Prof. W. M. Cumming, O.B.E.—*Chemical industries in Scotland.*

September 2

JOINT DISCUSSION with Section I (Physiology) on *The use of tracer elements, stable and radioactive, in biology and chemistry.*

Chairman : Sir Henry Dale, O.M., G.B.E., F.R.S.

Prof. W. F. K. Wynne-Jones.—*The use of Deuterium in chemical investigations.*

Dr. A. S. McFarlane.—*Biochemical applications of isotopes.*

Prof. J. H. Gaddum, F.R.S.—*Physiological and medical applications of isotopes.*

SECTION C

GEOLOGY

August 28

Prof. D. E. Innes.—*The geology of the Dundee district.*

DISCUSSION on *The raised beaches of the Forth and Tay.*

Dr. J. B. Simpson.—*The succession of events in the Forth and Tay area in post-glacial time.*

Mr. F. W. Anderson.—*Faunal evidence for changes in climate and elevation of land.*

Mr. J. Knox.—*Late glacial phenomena in East Fife.*

Dr. R. Campbell.

August 29

Dr. Scott Simpson.—*Some features of the geomorphology of north-east Scotland.*

Mr. F. W. Anderson.—*The Calciferous Sandstone series of East Fife.*

Dr. J. Pringle.—*The probable equivalence of the Dalradian series of Islay with the Eo-Cambrian and Cambrian rocks of southern Norway, Finmark, north-east Spitzbergen and East Greenland.*

Dr. G. W. Tyrrell.—*Differentiation of picrite-teschenite sills as illustrated by recent borings.*

Dr. A. G. MacGregor.—*Problems of Carboniferous-Permian volcanicity in Scotland.*

Dr. J. Weir.—*Note on the occurrence of Anthraconauta scotica in the Lower Limestone group of the Scottish Carboniferous.*

September 1

PRESIDENTIAL ADDRESS by Dr. M. Macgregor on *Geology in the development of the coalfields.*

DISCUSSION on *The future of coal supplies.*

Prof. H. G. A. Hickling, F.R.S.—*The origin and maturation of coals.*

Dr. A. C. Monkhouse.—*Achievements of the physical and chemical survey of the coal resources.*

Dr. C. A. Seyler.—*Petrographic evidence of coal development.*

Dr. G. H. Mitchell.—*Possible extensions to the midland coalfields of England.*

Dr. G. M. Lees.—*Geophysical evidence of the prospects of new coalfields.*

Dr. R. Holroyd.—*Coal as a chemical raw material.*

Dr. J. K. Allan.

September 2

Mr. D. S. Watt and Dr. T. S. Westoll.—*The Old Red Sandstone of the Pennan area, north Aberdeenshire.*

Dr. J. G. C. Anderson.—*The stratigraphical nomenclature of Scottish metamorphic rocks.*

Prof. D. L. Linton.—*The ideal geological map.*

Dr. J. F. Scott.—*The Larachbeg black shale, Morvern, Argyll.*

Dr. T. S. Westoll.—*The New Red Sandstone of the Elgin area.*

Dr. A. Lamont.—*The Gala-Tarannon neritic fauna of the Pentland Hills near Edinburgh.*

September 3

Announcements of researches recently completed or in progress.

Sir Edward Bailey, F.R.S., and Prof. W. Q. Kennedy.—*Moines and Torridonian.*

Dr. L. R. Moore.—*The microstructure of oil shales.*

Prof. W. T. Gordon.—*Sedimentary analcite.*

SECTION D

ZOOLOGY

August 28

PRESIDENTIAL ADDRESS by Dr. Edward Hindle, F.R.S., on *Zoologists in war and peace.*

JOINT DISCUSSION with Section B (Chemistry) and M (Agriculture) on *Insecticides.* (*See entry under Section B*).

DISCUSSION on *Parasitology.*

Dr. E. L. Taylor.—*Some aspects of nematode infection.*

Dr. W. Stephenson.—*Formation of the egg-shell in the Liver Fluke,* Fasciola hepatica.

Dr. J. D. Smyth.—*Cultivation of tape-worms* in vitro.

Dr. W. R. Kerr.—*Trichomoniasis in the bovine.*

Mr. C. Horton-Smith.—*Coccidiosis.*

August 29

DISCUSSION on *The depletion of wild animal populations.*

Prof. J. Ritchie.—*The present status.*

Dr. F. Fraser Darling.—*Mammals in Great Britain.*

Prof. Dr. G. J. van Oordt.—*The effect of bird protection on population numbers in the Netherlands.*

Dr. J. Berry.—*Freshwater fisheries.*

Dr. G. C. L. Bertram.—*Marine fisheries.*

September 1

DISCUSSION on *Animal behaviour.*

Dr. W. H. Thorpe.—*Recent advances in animal psychology.*

Mr. P. H. T. Hartley.—*Recognition of predators in birds.*

Prof. D. B. Johnstone-Wallace.—*The mechanical recording of eating behaviour in the dairy cow.*

Miss Winifred M. Phillips.—*Some problems associated with the control of the rabbit.*

JOINT DISCUSSION with Section K (Botany) on *Genetics of lower organisms.* (*See entry under Section K.*)

September 2

DISCUSSION on *Taxonomy.*

Dr. H. W. Parker.—*The museum systematist.*

Mr. Francis Hemming, C.M.G., C.B.E.—*The work of the International Commission.*

Prof. S. Zuckerman, C.B., F.R.S.—*Taxonomy and human evolution.*

Prof. H. R. Hewer.—*Applications and teaching of taxonomy.*

Dr. R. Dennell.—*Insect and crustacean cuticles.*

Miss Sheila S. Lyon and Miss Avis Brindley.—*The feeding movements of the Acorn Barnacle* (Balanus balanoides).

Mr. M. W. H. Bishop and Mr. W. R. Hunter.—*Some biological aspects of anti-fouling.*

SECTION E

GEOGRAPHY

August 28

Mr. S. J. Jones.—*Dundee.*

Mr. A. Davies.—*Changing values in military geography.*

PRESIDENTIAL ADDRESS by Prof. Eva G. R. Taylor on *The geographer in war and peace.*

August 29

DISCUSSION on *The geography of Scotland and the Geographer's approach to its problems.*

Dr. J. F. Scott.—*Morvern, a geographical study.*

Miss P. M. Hobson.—*Lewis, a crofting area.*

Mr. J. M. Houston.—*Village planning in Scotland 1745–1845.*

Dr. Catherine Snodgrass.—*A geographer's approach to Scotland's problems.*

Discussion opened by Prof. A. G. Ogilvie, O.B.E.

The Registrar-General of Scotland, Mr. J. G. Kyd, C.B.E., spoke on the Third Statistical Account of Scotland.

September 1

DISCUSSION on *Urban geography.*

Mr. A. E. Smailes.—*The analysis and delimitation of urban 'fields.'*

Dr. E. R. Dickinson.—*The standardised mapping of urban zones illustrated from west European cities.*

Mr. J. P. Haughton.—*The social geography of Dublin.*

Papers on *Some population problems.*

Mr. T. W. Freeman.—*Population density and emigration in Ireland.*

Mr. R. W. Steel.—*The geography of the population of Ashanti, Gold Coast.*

Dr. A. Geddes.—*Geography, sociology and psychology: a plea for co-ordination with an example of method applied to India's population.*

September 2

DISCUSSION on *The National Atlas.*

Speakers included representatives from the Department of Health for Scotland, the Ministry of Town and Country Planning, The Ordnance Survey and of Sections C, D and H.

Dr. H. C. K. Henderson.—*Our changing agriculture.*

SECTION F

ECONOMICS AND STATISTICS

August 28

Mr. J. K. Eastham.—*Compensation in nationalised industries.*

Mr. R. F. Henderson.—*The significance of the new issue market for the finance of industry.*

Mr. F. Sewell Bray.—*Social accounting.*

Mr. R. F. Harrod.—*The work of Lord Keynes.*

August 29

PRESIDENTIAL ADDRESS by Prof. Dennis H. Robertson on *The economic outlook.*

Mr. T. Wilson.—*Profit and enterprise.*

Mr. D. McCurrach.—*Britain's U.S. Dollar problems 1939/45: a commentary.*

September 1

Mr. D. J. Morgan.—*Industrial development and labour in South Africa.*

Dr. D. Black.—*Value and equilibrium in economic and political science.*

Dr. H. Bernardelli.—*The influence of monetary organisation on the duration and dampening of trade cycles.*

September 2

Sir Garnet Wilson, J.P.—*The industrial development of Dundee.*

Mr. W. B. D. Brown.—*Proposed code of industrial management.*

Joint Discussion with Section J (Psychology) on *Incentives in industry.*

Speakers: Dr. J. A. Bowie, Mr. C. Madge, Mr. D. Chapman, Mrs. W. Raphael and Miss N. M. Davis.

SECTION G

Engineering

August 28

Presidential Address by Sir William Halcrow on *Progress in Modern Engineering.*

Papers on *Soil mechanics:*

Mr. N. Cochrane.—*Earth and water.*

Mr. H. Ridehalgh.—*Graving docks.*

August 29

Professor Jack Allen.—*Hydraulic models.*

Dr. A. W. Hendry.—*The testing of certain structural connections with reference to the variations in strength of welded constructions.*

Wing-Comdr. T. R. Cave-Brown-Cave.—*Roof-top roadways—general plan.*

Mr. D. H. McPherson.—*Roof-top roadways—design.*

September 1

Mr. J. Henderson.—*Scottish water power development, with special reference to electrical problems.*

Mr. P. G. M. Dawe.—*The mechanism of oscillation in phase-shift oscillators.*

Mr. H. B. Seed.—*The effects of creep and shrinkage in reinforced concrete structures.*

September 2

Mr. Forrest S. Anderson on *Mechanisation of coal mines, with special reference to coal-cutting machinery.*

Mr. W. D. Garrick.—*Applied X-Rays: the non-destructive examination of butt-welds.*

Dr. J. A. Pope.—*An analysis of 'size effect' in normalised mild steel.*

SECTION H

Anthropology and Archæology

August 28

Mr. D. B. Harden.—*Romano-Egyptian lamps: an essay in classification.*

Mr. A. D. Lacaille.—*Earliest settlers in the east of Scotland.*

Prof. Gerhard Bersu.—*Duns, Raths, Crannogs and Cashels.*

Mr. C. N. Johns.—*The Early Arab Palace recently found near Jericho.*

Mr. R. U. Sayce.—*The development and organisation of folklife studies.*

Rev. Canon J. A. MacCulloch.—*A widespread superstition: the fairy changeling and the origin of the belief.*

Prof. H. J. Rose.—*The folklore of a Greek island.*

Mrs. N. K. Chadwick.—*Early European ghost stories: a comparative study.*

August 29

Presidential Address by Prof. C. Daryll Forde on *The anthropological approach to social science.*

Prof. E. O. James.—*The significance of myth and ritual in primitive society.*

Prof. J. Murphy.—*The primitive relations and psychology of magic and religion.*

Miss I. F. Grant.—*The making of a Scots Folk museum.*

Discussion on *Dating the past.*

Prof. F. E. Zeuner.—*Recent work on absolute chronology.*

Mr. A. Leslie Armstrong.—*Evidence of Lower Palæolithic man in the north of England, and its bearing upon relative chronology.*

Dr. K. P. Oakley.—*The possible use of micro-determination of fluorine in relative dating of bones.*

Dr. H. Godwin.—*The principles and practice of dating archæological remains by pollen analysis.*

September 1

Discussion on *Culture change.*

Dr. A. I. Richards.—*The problem and the approach.*

Dr. L. P. Mair.—*A study of change in African land rights.*

Dr. K. L. Little.—*A study of modern social change in a West African community.*

Dr. C. von Fürer-Haimendorf.—*The aboriginal problem in Hyderabad (Deccan).*

Mrs. J. F. Danielli.—*The Ambaniandro (Madagascar) theory of social structure and its relation to the theories of Eddic Scandinavian and Confucian Chinese literature.*

Mrs. Marguerite Milward.—*Some primitive tribes of India : the Maria-Gonds, Saoras and Khonds.*

Mr. J. Hornell.—*Paddles, oars and rowlocks : development and distribution.*

Mr. A. Leslie Armstrong.—*The recent discovery of a Palæolithic skull in Derbyshire.*

September 2

Mr. L. V. Grinsell.—*The folklore of prehistoric monuments.*

Mr. J. M. Davidson.—*The folklore of some Scottish antiquities.*

Prof. Stuart Piggott.—*Highland and lowland zones in the British Early Bronze Age.*

Mr. Angus Graham.—*Linear earthworks in southern Scotland.*

Sir Richard Paget, Bt., and Mr. E. S. Greenaway.—*The education of the totally deaf child.*

Prof. W. E. Le Gros Clark, F.R.S.—*Fossil hominoidea recently discovered in Africa.*

Dr. J. S. Weiner.—*Metabolism and race in the tropics.*

Prof. D. R. Dow.—*Recent finds of short cists in the Dundee area.*

SECTION I

Physiology

August 28

Discussion on *Man and the machine : physiological and psychological factors affecting human efficiency.*

Prof. R. C. Browne.—*Physiology, psychology and efficiency.*

Prof. W. E. Le Gros Clark, F.R.S.—*The application of anatomy to the design of man-operated machines.*

Dr. P. Hugh-Jones.—*Man's muscular power.*

Prof. R. E. Lane.—*Man and the machine.*

August 29

Joint Discussion with Sections B (Chemistry) and K (Botany) on *Penicillin and other antibiotics.*

Chairman : Prof. Winifred Cullis, C.B.E.

Sir Alexander Fleming, F.R.S.—*Penicillin and other antibiotics.*

Dr. E. Chain.—*The chemistry of antibiotics and their biological properties.*

Dr. J. Ramsbottom.—*The biological aspect.*

Dr. J. A. Elvidge.—*Penicillin : some contributions to its chemistry and synthesis.*

Dr. P. W. Brian.—*Fungistatic antibiotics.*

Dr. S. E. Michael.—*Chemical structure of some mould metabolic products, including antibiotics.*

September 1

Presidential Address by Professor Winifred Cullis, C.B.E., on *Physiology and the Community.*

Discussion on *Aviation physiology.*

Air-Marshal Sir Harold Whittingham, K.C.B., K.B.E.

Dr. C. F. Code, Dr. E. H. Wood, Dr. Edward H. Lambert and Dr. E. J. Baldes.—*Man's reaction to centrifugal force.*

S./Ldr. W. K. Stewart.—*Human reactions to accelerations and decelerations.*

S./Ldr. A. Barwood.—*Altitude problems.*

F./O. D. A. W. Edwards.—*Effects of noise in aviation.*

Discussion on *Climate and Health.*

Prof. H. C. Bazett.—*Human efficiency as affected by climate and its relation to social development.*

Dr. N. H. Mackworth.—*Human abilities in hot and humid surroundings.*

Dr. N. C. Wright and Dr. J. D. Findlay.—*The influence of climate on live stock.*

Prof. M. N. J. Dirken.—*Air-ions and health.*

September 2

Joint Discussion with Section B (Chemistry) on *The use of tracer elements, stable and radioactive, in biology and in chemistry.* (*See entry under Section B.*)

SECTION J

PSYCHOLOGY

August 28

Prof. T. H. Pear.—*Perspectives in modern psychology.*

Mr. D. C. Fraser.—*A note on Humphrey's paradox.*

Mr. G. Gorer.—*The scientific study of national character.*

Prof. H. V. Dicks.—*Personality traits and political ideology—a field study on German prisoners.*

Mr. C. A. Oakley and Dr. H. S. Phillips.—*Rehabilitation of an industrially depressed area.*

Dr. J. D. Uytman.—*Considerations on the place of psychologist and psychiatrist in industry.*

Miss A. E. Sladden.—*Spelling defects in cases of brain lesion.*

August 29

DISCUSSION on *Selection for Management* :—
Speakers : Mr. A. Rodger, Dr. T. Ferguson Rodger, and Dr. N. A. B. Wilson.

PRESIDENTIAL ADDRESS by Dr. S. J. F. Philpott on *Man's adaptability.*

Mr. D. Straker.—*Standards of acceptance in vocational selection.*

Mr. J. C. Raven.—*Changes in mental abilities with age.*

Dr. P. E. Vernon.—*Changes in abilities from* 14 *to* 20 *years.*

September 1

JOINT DISCUSSION on *The allocation of children for secondary education.* (*See entry under Section L.*)

September 2

DISCUSSION on *The methods of public opinion surveys.*

Mr. H. Durant.—*Do the public tell the truth ?*

Dr. H. J. Eysenck.—*Equal-interval scales or single-question surveys : an experimental study.*

Mr. J. R. Clark.—*Attitudes of school-children to interest in team games and to compulsory team games.*

Miss N. E. Robertson and Dr. J. A. Waites.—*The educational and social background of English judges.*

Dr. M. Sturt.—*The part of the psychologist in the moral development of society.*

Dr. R. W. Pickford.—*Experiments with pictures.*

Dr. J. Hettinger.—*Psychometric telepathy across the Atlantic.*

JOINT DISCUSSION with Section F (Economics) on *Incentives in industry.* (*See entry under Section F.*)

SECTION K

BOTANY

August 28

PRESIDENTIAL ADDRESS by Dr. H. Hamshaw Thomas, M.B.E., F.R.S., on *The history of plant form.*

Mr. K. R. Sporne.—*A new approach to the problem of the primitive flower.*

Prof. Dr. H. J. Lam.—*Classification and the new morphology.*

Prof. J. Walton.—*The morphology of Pteridosperm cupules.*

August 29

JOINT DISCUSSION with Sections B (Chemistry) and I (Physiology) on *Penicillin and other antibiotics.* (*See entry under Section I.*)

DISCUSSION on *Raspberry and strawberry diseases.*

Dr. R. V. Harris.—*Introduction.*

Dr. C. H. Cadman.—*Some virus disease problems in raspberries.*

Dr. I. W. Prentice.—*Strawberry virus diseases.*

Mr. R. D. Reid.—*Strawberry disease investigations at Auchencruive.*

Dr. C. J. Hickman.—*Root-rots of strawberry.*

Dr. F. C. Bawden.—*Potato virus diseases.*

September 1

Mr. A. S. Thomas.—*Ecology in tropical Africa.*

Dr. K. H. Rechinger.—*Evolution lines and geographical distribution in the subgenus Lapathum of Rumex.*

Mr. F. T. Walker.—*Some results of the littoral and sublittoral seaweed survey of Scotland,* 1945–47.

Mr. W. E. J. Milton.—*The buried viable seed populations of lowland and upland soils with particular reference to those of grasses and clovers.*

Mr. Herbert Jones.—*A contribution to the ecological study of a formerly polluted river in Cardiganshire.*

Wing-Cmmdr. T. R. Cave-Browne-Cave, C.B.E.—*The draining of Binley Lake and its ecological consequences.*

JOINT DISCUSSION with Section D (Zoology) on *Genetics of lower organisms.*

Dr. K. Mather.—*Inheritance in Paramœcium.*

Dr. F. W. Sansome.—*The genetical analysis of bacteria and phage.*

Mr. H. L. K. Whitehouse.—*Sex and heterothallism in the fungi.*

Mrs. E. R. Sansome.—*The genetics of yeast.*

Dr. G. Pontecorvo.—*General implications of recent progress in the genetics of micro-organisms.*

September 2

Dr. G. F. Asprey.—*A new method for the simultaneous measurement of gaseous exchanges in plant tissues.*

Dr. L. J. Audus.—*Selective phytocidal actions of dichloro-phenox acetic acid and coumarin.*

Mr. J. G. Boswell.—*Observations on the metabolism of the ' root ' of Brassica Napus L.*

Dr. A. S. Boughey.—*Some new aspects of fungal ecology.*

Prof. J. Small.—*Laws of organic evolution.*

SUB-SECTION K*

FORESTRY

August 28

Mr. A. H. Gosling, Chairman's Address on *Developments in Scottish forestry.*

Modern nursery practice :—
Dr. A. B. Stewart.—*Maintenance of fertility.*
Mr. J. A. B. Macdonald.—*Mechanisation and nurseries.*
Dr. E. M. Crowther.—*Nutrition problems.*
Mr. W. H. Guillebaud.—*General aspects.*

August 29

The larch in British forestry :
Mr. James Macdonald.—*Silviculture.*
Dr. W. R. Day.—*Diseases of larch.*

September 1

Mr. M. V. Laurie.—*Potentiality of forest tree genetic research.*

SECTION L

Education

August 28

Sir Garnet Wilson, J.P.—*Scottish education to-day.*
Sir Peter D. Innes, C.B.E.—*The National Foundation for Educational Research.*
Miss C. M. Lambert.—*An aspect of educational research : problems of selection techniques with borderline groups at the age of transfer into secondary schools.*

August 29

Presidential Address by Miss Lynda Grier on *The evolution of secondary education in England.*
A review of *Education in the Services.*
Speakers : Air-Commodore A. H. Robson, O.B.E., M.C., Mr. L. J. F. Brimble.

September 1

Joint Discussion with Section J (Psychology) on *The allocation of children for secondary education.*
Chairman : Miss Lynda Grier.
Dr. F. M. Earle.—*The significance of ability differences at eleven plus.*
Dr. R. H. Thouless.—*The use of intelligence tests for Grammar School selection.*
Mr. W. O. Lester Smith, C.B.E.
Mr. Douglas M. McIntosh.

September 2

U.N.E.S.C.O. Joint Session with Division for Social and International Relations of Science.
Speakers : Sir John Maud, Prof. F. J. M. Stratton, F.R.S., Dr. H. Allen, Mr. M. C. Pottinger and Mr. Ritchie Calder.

SECTION M

Agriculture

August 28

Presidential Address by Dr. W. G. Ogg on *Soil and health.*
Joint Discussion with Section B (Chemistry) and D (Zoology) on *Insecticides.* (*See entry under Section B.*)

August 29

Discussion on *The biology of the soil.*
Dr. H. G. Thornton, F.R.S.—*The micro-population of the soil.*
Dr. A. C. Evans.—*Reciprocal relations between earthworms and soil.*
Mr. G. G. McCall.—*Agriculture in Angus.*

September 1

Discussion on *Recent advances in the control of animal diseases.*
Prof. T. Dalling.—*Control of some of the diseases affecting dairy cattle.*
Dr. W. S. Gordon.—*Causes and control of infective diseases of hill sheep.*
Dr. J. Stewart.—*Deficiency diseases and their control.*

September 2

Discussion on *Could and should Britain feed herself?*
Rt. Hon. Walter Elliot, F.R.S., M.P.—*How far can Britain feed herself?*
Prof. J. R. Marrack, D.S.O., M.C.—*Nutritional requirements as a basis of a home food production plan.*
Mr. H. D. Walston.—*Some implications of agricultural self-sufficiency.*

REFERENCES TO PUBLICATION OF COMMUNICATIONS TO THE SECTIONS

AND OTHER REFERENCES SUPPLIED BY AUTHORS

(As at Jan. 15, 1948)

The titles of discussions, or the names of readers of papers in the Sections, as to which publication notes have been supplied, are given below in alphabetical order under each Section.

References indicated by 'cf.' are to appropriate works quoted by the authors of papers, not to the papers themselves.

General reference may be made to the issues of *Nature* from September 1947 onwards.

Section A

Discussion on 'The peace-time applications of nuclear fission,' 1947 *Nature*, **160**, 451.

Booker, Dr. H. G. 1946 *J.I.E.E.* **93**, Part 3a, No. 1, 69–78. Cf. Booker, H. G. and Walkinshaw, W. 'The mode theory of tropospheric refraction and its relation to wave-guides and diffraction,' 1946 *Meterological factors in radiowave propagation*, pp. 80–127, *Phys. Soc. & Royal Met. Soc.*

Cockcroft, Dr. J. D. 1947 *Nature*, **160**, 451. Cf. 1947 *Nature*, **160**, 182.

Dymond, Dr. E. G. 1947 *Proc. Phys. Soc.*, **59**, 645.

Fox, Dr. L. To appear in *J. of Mechanics and App. Maths.*

Garlick, Dr. G. F. J. To appear in *Journal of the Institution of Electronics*. Cf. 'Short period phosphorescence and electron traps,' Garlick, G. F. J. and Wilkins, M.H.F. 1945 *Proc. Roy. Soc. A.* **184**, 408; 'Electron traps and dielectric changes in phosphorescent solids,' Garlick G. F. J. and Gibson, A. F.; 1947 *Proc. Roy. Soc. A.* **188**, 485.

Hey, J. S. Cf. 'Solar radio noise,' Appleton, E. and Hey, J. S. 1946 *Phil. Mag.*, **37**, 73; 'Radar observation of meteors,' Hey, J. S. and Stewart 1947 *Proc. Phys. Soc.*, **59**, 847.

Jones, G. A. Cf. 'Photography by infra-red' Clark W., expected to appear in *Discovery*.

Lee, Dr. E. A summary will appear in *Reports of Progress in Physics*.

Lovell, Dr. A. B. Cf. 'Radio echo observations of meteors,' *Monthly Notices of Roy. Astronom. Soc.*, Vol. 107, 1947.

Ryle, M. Expected to appear in *Proc. Roy. Soc.* Cf. 1946 *Nature*, **158**, 339; 1947 *Nature*, **160**, 157.

Sutherland, Dr. G. B. B. M. Expected to appear in Vol. 11 of *Reports on Progress in Physics*. Cf. 1946 *Nature*, **158**, 873; 1947 *Nature*, **160**, 567; 1947 *Proc. Phys. Soc.*, **59**, 77.

Thring, M. W. Oct. 1947 *Coke and Gas*, p. 299.

Sub-section A*

MacNeille, Dr. H. M. Cf. 'Extensions of measure,' 1938 *Proc. Nat. Acad. Sc.*, **24**, 188–193; 'A unified theory of integration,' 1941 *Proc. Nat. Acad. Sc.*, **27**, 71–76.

Neumann, Dr. B. H. Cf. 'On some affine invariants of closed convex regions,' 1939 *J. Lond. Math. Soc.*, **14**, 262–272; 'On an invariant of plane regions and mass distribution,' 1946 *J. Lond. Math. Soc.*, **20**, 226–237.

Section C

Report of the discussion on 'The future of the coal supplies,' 1947 *Nature*, **160**, 593.

Anderson, F. W. To appear in *Trans. Edin. Geol. Soc.*

Bailey, Sir Edward. Cf. 'Caledonian tectonics and metamorphism in Skye,' 1939 *Bull. Geol. Surv. of Gt. Britain*, **2**, 46; Read, H. H. 'Geology of Central Sutherland,' 1931 *Mem. Geol. Surv.*; Read, H. H. 'Age-problems of the Marine Series of Scotland,' 1934 *Geol. Mag.*, **51**, 302.

Gordon, Prof. W. T. Expected to appear in *Geol. Mag.*

Lamont, Dr. A. Cf. 'Gala-Tarannon beds in the Pentland Hills, near Edinburgh,' 1947 *Geol. Mag.*, **84**, 193–208, 289–303.

Scott, Dr. J. F. Expected to appear in *Trans. Geol. Soc. Edin.*

Section D

Berry, Dr. J. Cf. 'Salmon research and the development of the salmon fisheries,' 1944 *Proc. Roy. Phil. Soc. Glasgow*, **68**, Part 4.

Bishop, M. W. H. Cf. 1947 *Nature*, **159**, 501.

Boyd, Dr. Elizabeth M. Cf. 'A survey of the external parasites and the parasites of the digestive tract and its derivatives of the starling in North America,' 1946 *Anat. Record*, **96**, No. 4, p. 21.

Brindley, Miss Avis. Expected to appear as a note in *Nature*.

Horton-Smith, C. To appear in *Veterinary Record*.

Smyth, Dr. J. D. Cf. 1946 *J. Exp. Biol.*, **23**, 47; 1947 *Biol. Rev.*, **22**, 214; 1947 *Parasitology*, **38**, 173.

Spaul, Prof. E. A. 1947 *Proc. Zoo. Soc.*, No. 116, 739.

Stephenson, Dr. W. 1947 *Parasitology*, **38** (3), 128–139

Taylor, Dr. E. L. To appear in *Veterinary Record*.

Thorpe, Dr. W. H. To appear in *Bull. Inst. Animal Behaviour*.

Section E

Davies, A. Cf. 'Geographical factors in the invasion and battle of Normandy,' *Geog. Review*, Oct. 1946.

Freeman, T. W. Cf. 'Migration movements and the distribution of population in Eire,' 1938 *Journal of the Statistical and Social Inquiry Society of Ireland*, **16**, 89–104.

Hobson, Miss P. M. Expected to appear in *Scot. Geog. Mag.* Cf. 'Durness Parish,' *Scot. Geog. Mag.* Sept. 1947.

Scott, Dr. J. F. Expected to appear in *Roy. Scot. Geog. Soc. Mag.*

Smailes, A. E. 1947 *Geography*, **32**, December issue. Cf. 'The urban hierarchy in England and Wales,' 1944 *Geography*, **29**; 'The urban mesh of England and Wales,' 1946 *Trans. Inst. Brit. Geographers*; 'The sphere of influence of Middlesbrough,' 1947 *Middlesbrough Survey and Plan*, pp. 75, 83.

Snodgrass, Dr. Catherine P. Cf. ' The density of agricultural population in Scotland, with English and European comparisons,' 1941 *Geog. Journ.*, **97,** No. 4 ; ' Recent population changes in Scotland,' 1944 *Scot. Geog. Mag.*, **60,** Sept. ; ' Notes on the geographical distribution of employment in Scotland,' *Scot. Geog. Mag.* **60,** December.

Steel, R. W. Expected to appear in *Africa* or *Geog. J.*

Section F

Bernadelli, Dr. H. Expected to appear in *Econometrica*, Chicago.

Bray, F. S. 1947, *The Accountant*, Aug. 30, Sept. 6.

Eastham, J. K. To appear in Jan. 1947 issue of *Manchester School.*

Henderson, R. F. To appear in *Economic Journal.*

McCurrach, D. Expected to appear in *Economic Journal.*

Madge, C. 1948 *Occupational Psychology*, **22,** No. 1.

Section G

For a general report of the papers given to Section G see *Engineering*, Sept. 5 and Sept. 12, 1947.

Allen, Prof. J. 1947 *Engineering*, Sept. 5, pp. 231–232, 238 ; 1947 *Engineer*, Sept. 12, pp. 242–243.

Anderson, Forrest S. 1947 *Engineering*, Oct. 17, pp. 381–384.

Cave-Brown-Cave, Wing-Cmdr. T. R. 1947 *Engineering*, Sept. 26, p. 294.

Cochrane, H. 1947 *Engineering*, Aug. 29, p. 213.

Dawe, P. G. M. 1947 *Engineering*, Oct. 31, p. 429.

Garrick, W. D. 1947 *Engineering*, Oct. 24.

Henderson, J. 1947 *Engineering*, Oct. 3, Oct. 10.

Hendry, Dr. A. W. 1947 *Engineering*, Sept. 12, p. 261.

McPherson, D. H. 1947 *Engineering*, Sept. 26, p. 294.

Pope, Dr. J. A. 1947 *Engineering*, Sept. 19, p. 284.

Ridehalgh, H. 1947 *Engineering*, Sept. 5, p. 239.

Seed, H. B. 1947 *Engineering*, Sept. 26.

Section H

Chadwick, Mrs. N. K. Cf. ' Lug Scéith Scál Find,' 1934 *Scottish Gaelic Studies*, **4,** 1 ; ' Norse ghosts,' 1946 *Folk-Lore*, **57.**

Clark, Prof. W. E. Le Gros. Cf. ' The importance of the Fossil Australopithecinae in the study of human evolution,' 1947 *Science Progress*, **139,** 377 ; ' Observations on the anatomy of the Australopithecinae ' to appear in *J. of Anat.*

Hornell, J. Cf. ' Constructional parallels in Scandinavian and Oceanic boat construction,' 1944 *J. Polynesian Soc.*, **53,** 43–58 ; 1946 *Water transport : origins and early evolution*, Cambridge ; ' The significance of the dual element in British fishing-boat construction,' 1946 *Folk-liv*, pp. 113–126, Stockholm.

James, Prof. E. O. Cf. 1940 *The social function of religion*, L.U.P.

Johns, C. N. Cf. articles by D. C. Baraucki and by R. W. Hamilton in *Quarterly of the Department of Antiquities in Palestine*, Geoffrey Cumberlege, O.U.P., London.

Grinsell, L. V. Expected to appear in *Folk-lore.* Cf. ' Some aspects of the folk-lore of prehistoric monuments,' 1937 *Folk-lore*, **48** ; ' Scheme for recording the folk-lore of prehistoric remains,' 1939 *Folk-lore*, **50** ; ' The folk-lore of ancient Egyptian Monuments,' 1947 *Folk-lore*, **58.**

MacCulloch, Rev. Canon J. A. Cf. *Hastings Encyclopedia of Religion and Ethics*, **iii,** 358–363 and **v,** 678–689 ; 1932 *Mediaeval Faith and Fable*, Ch. 2.

Milward, Mrs. M. Expected to appear in *Man.*

Piggott, Prof. S. Expected to appear in *Antiquity.* Cf. ' The early bronze age in Wessex,' 1938 *Proc. Prehist. Soc.*, **4,** 52–106.

Sayce, R. U. To appear in *The Montgomeryshire Collections* (1947).

Weiner, Dr. J. S. Expected to appear in *Journal of Royal Anthropological Institute* or *Man.* Cf. ' Some remarks on physiological anthropology,' 1946 *Man.*, No. 76.

Section I

Report of the discussion on ' Penicillin and other anti-biotics,' 1947 *Nature*, **160,** 554.

Brian, Dr. P. W. 1947 *Nature*, **160,** 554. Cf. ' Production of antifungal and antibacterial substances by fungi,' Brian, P. W. and Hemming, H. G. 1947 *J. Gen. Microbiol.* **1,** 158.

Browne, Prof. R. C. Expected to appear in *Brit. J. Indus. Med.* Cf. ' A conception of industrial health,' 1947 *Brit. Med. J.*, **i,** 838 ; ' Miners' Nystagmus,' *Iron and Coal Trades Review*, Nov. 1947.

Clark, Prof. W. E. Le Gros. Cf. ' Some anatomical problems in Naval Warfare,' Weddell, G. and Darcus, H. D. 1947 *Brit. J. Indus. Med.*, **4,** No. 2, 77.

Code, A. C. F. Cf. ' The problem of blackout and unconsciousness in aviators ' Lambert, E. H. and Wood, E. H. 1946 *Medical Clinics of North America, Mayo Clinic Number*, July, pp. 833–844 ; ' Effects of acceleration in relation to aviation,' Wood, E. H., Lambert, E. H., Baldes, E. J. and Code, C. F. 1946 *Federation Proceedings*, **5,** 327–344.

Gaddum, Prof. J. H. Cf. ' The use of isotopes in biology,' 1946 *Edin. Med. J.*, **53,** 284.

Hugh-Jones, Dr. P. Cf. ' The effect of limb position in seated subjects on their ability to utilise the maximum contractile force of the limb muscles,' 1947 *J. Physiol.* **105,** 332 ; ' The effect of seat position on the efficiency of bicycle pedalling,' 1947 *J. Physiol.* **106,** 186–193.

McFarlane, Dr. A. S. 1947 *Brit. Med. J.*, Nov. 15, p. 766.

Michael, Dr. S. E. Cf. Brian, P. W. 1947 *Nature*, **160,** 554 ; Raistrick *et al*, ' Patulin,' 1943 *Lancet*, **245,** 625.

Section J

The discussion on selection for management is reported in 1947 *Nature*, **160,** 512.

Clarke, J. R. Expected to appear in *Brit. J. Educ. Psych.*

Durant, Dr. H. To appear in *Public Opinion Quarterly.* Cf. 1945 *Biology and Human Affairs*, **2,** No. 2.

Earle, Dr. F. M. *Occupational Psychology*, Oct.

1947. Cf. 1936 *Tests of ability for secondary school courses*, L.U.P. ; 1944 *Reconstruction in the secondary school*, L.U.P. ; 1935 *A vocational guidance experiment in Fife*, Nat. Inst. Indus. Psych.

Fraser, D. C. To appear in *Brit. J. Psych.*

Hettinger, Dr. J. 1947 *J. Amer. Soc. Psyhcial Research*, July, pp. 94–122. Cf. 'The ultra-perceptive faculty' ; 'Explaining the ultra-perceptive faculty.'

Pear, Prof. T. H. To appear in *Brit. J. Psych.* Cf. 'The trivial and popular in psychology,' 1940 *Brit. J. Psych.*, **33,** 115–128 ; 'The social status of the psychologist and its effect upon his work,' 1942 *Sociological Review*, **34,** 68–81.

Straker, D. Expected to appear in *Occupational Psychology.*

Section K

Audus, Dr. L. J. Cf. 'A new soil-perfusion apparatus,' *Nature*, **158,** 419 ; 'Coumarin as a selective phytocidal agent,' with Dr. J. H. Quastel, *Nature*, **159,** 320.

Boughey, Dr. A. S. To appear in *Trans. Brit. Myc. Soc.* Cf. 'The effect of rainfall on plant disease distribution in the Anglo-Egyptian Sudan,' 1947 *Myc. Papers*, No. 19, Imperial Mycological Institute, Kew.

Cadman, C. H. A note on insect transmission of raspberry viruses is expected to appear in *Nature.*

Lam, Prof. Dr. H. J. 1947 *Acta Biotheoretica*, 8, part 4.

Milton, W. E. J. Cf. 'The buried viable seeds of enclosed and unenclosed hill-land,' 1936 *Bull. Welsh Plant Breeding Station*, Series H, No. 14, 58–84 ; 'On the viable seeds present in the soils beneath pastures,' Chippendale, H. G. and Milton, W. E. J. ; 1934 *J. Ecol.* **22,** 508–531.

Prentice, Dr. I. W. Cf. 'Resolution and synthesis of virus complexes causing strawberry yellow-edge,' 1946 *Nature*, **158,** 24.

Rechinger, Dr. K. H. Expected to be published by the Botanical Society of Great Britain. Cf. 'Vorarbeiten zu einer Monographie der Gattung Rumex' ; I. *Beihefte zim Botanischen Centralblatt*, Bd. 49, 1932 Abt. II, 1–132 ; II. *Feddes Repetorium spec. nov.* Bd. 31, 1933, 225–283 ; III. *Arkiv fur Botanik* Bd. 26 A 1933, No. 3, 1–58 ; IV. *Oesterr. Botanische Zeitschrift*, Bd. 84, 1935, 1–52 ; V. *Field Museum of Natural History Bot. Ser.*, Vol. 17, No. 1, 1–150 ; VI. *Botaniska Notiser* 1939, Lund 1939, 485–504.

Reid, R. D. Cf. 'Red core disease of the strawberry,' 1941 *Scot. J. Agric.*, **23,** 264–272 ; 1944 *Fruitgrower*, **97,** 9–10 and 29–30.

Spone, K. R. Expected to appear in *The New Phytologist.*

Thomas, A. S. Cf. 'The dry season in the Gold Coast and its relation to the cultivation of cacao,' *J. Ecol.*, **20,** 263–269 ; 'Vegetation of the Sese Islands, Uganda,' *Ibid.*, **29,** 330–353 ; 'Vegetation of the Karamoja District, Uganda,' *Ibid.*, **31,** 149–177 ; 'Vegetation of some hillsides in Uganda,' *Ibid.*, **33,** 10–43 and 153–172.

Walker, F. T. Littoral survey expected to appear in *Proc. Linn. Soc.*, sub-littoral survey expected to appear in *J. Ecol.*

Whitehouse, H. L. K. Expected to appear in *Biological Reviews.*

Sub-section K*

Laurie, M. V. Expected to appear in *Forestry.* Cf. 'The importance of seed origin in forestry,' 1939 *Indian Forester*, **65,** March.

Section L

Lambert, Miss C. M. Cf. 'A study of interest,' *Times Educational Supplement*, Feb. 1945 ; 'The use of school records,' *T.E.S.*, Sept. 1945 ; 'Testing in Northumberland,' *Education*, Sept. 1947.

McIntosh, D. M. Cf. 'Promotion from primary to secondary education,' to be published by the Scottish Council for Research in Education.

Section M

Evans, Dr. A. C. To appear in *Annals of Applied Biology.* Cf. 'Biological studies in the field,' 1947 *Ann. App. Biol.*, No. 3.

Gordon, Dr. W. S. Cf. 'Recent advances in the control of certain diseases of sheep,' 1934 *Vet. J.*, **90,** 439.

Stewart, Dr. J. To appear in *Scottish agriculture.* Cf. 'Pasture and its dangers to livestock,' 1946 *Proc. Nut. Soc.*, **4,** 64.

RESEARCH COMMITTEES, 1947–48

Grants of money, if any, from the Association for expenses connected with researches are indicated in heavy type.

SECTION A.—MATHEMATICS AND PHYSICS.

Seismological investigations.—Dr. R. Stoneley, F.R.S. (*Chairman*), Lt.-Col. E. Tillotson (*Secretary*), Mr. E. F. Baxter, Miss E. F. Bellamy, Prof. P. G. H. Boswell, O.B.E., F.R.S., Dr. E. C. Bullard, F.R.S., Dr. G. E. R. Deacon, F.R.S., Dr. A. T. J. Dollar, Dr. A. E. M. Geddes, O.B.E., Prof. G. R. Goldsbrough, F.R.S., Dr. Wilfred Hall, Dr. O. J. R. Howorth, O.B.E., Mr. J. S. Hughes, Prof. H. Jeffreys, F.R.S., Mr. Cosmo Johns, Dr. A. W. Lee, Prof. H. H. Plaskett, F.R.S., Prof. J. Proudman, F.R.S., Dr. A. O. Rankine, O.B.E., F.R.S., Rev. C. Rey, S.J., Rev. J. P. Rowland, S.J., Dr. F. J. Scrase, Dr. H. Shaw, Mr. J. J. Shaw, C.B.E., Sir Frank Smith, G.C.B., G.B.E., F.R.S., Dr. J. M. Stagg, Mr. P. L. Willmore.

Calculation of mathematical tables.—Dr. A. J. Thompson (*Chairman*), Dr. J. Wishart (*Vice-Chairman*), Dr. J. C. P. Miller (*Secretary*), Prof. W. G. Bickley, Dr. R. O. Cashen, Prof. R. A. Fisher, F.R.S., Dr. E. T. Goodwin, Dr. J. Henderson, Dr. J. O. Irwin, Mr. C. W. Jones, Prof. L. M. Milne-Thomson, Prof. E. H. Neville, Mr. D. H. Sadler, Mr. F. Sandon, Mr. W. L. Stevens, Mr. John Todd, Mr. M. V. Wilkes, Mr. J. R. Womersley. **£150.**

SECTIONS A, C.—MATHEMATICS AND PHYSICS, GEOLOGY.

The direct determination of the thermal conductivities of rocks in mines or borings where the temperature gradient has been, or is likely to be, measured.—Dr. Ezer Griffiths, F.R.S. (*Chairman*), Dr. D. W

Phillips (*Secretary*), Dr. E. C. Bullard, F.R.S., Dr. H. Jeffreys, F.R.S. (*from Section A*); Dr. E. M. Anderson, Prof. W. G. Fearnsides, F.R.S., Prof. G. Hickling, F.R.S., Prof. A. Holmes, F.R.S., Dr. J. Phemister, Dr. J. H. J. Poole (*from Section C*).

SECTION C.—GEOLOGY.

To excavate critical geological sections in Great Britain.—Prof. W. T. Gordon (*Chairman*), Prof. W. G. Fearnsides, F.R.S. (*Secretary*), Sir Edward Bailey, M.C., F.R.S., Dr. J. L. Begg, Mr. W. S. Bisat, F.R.S., Prof. P. G. H. Boswell, O.B.E., F.R.S., Prof. A. H. Cox, Mr. E. E. L. Dixon, Dr. Gertrude Elles, M.B.E., Prof. H. L. Hawkins, F.R.S., Prof. G. Hickling, F.R.S., Dr. R. G. S. Hudson, Prof. V. C. Illing, F.R.S., Prof. O. T. Jones, F.R.S., Dr. Murray Macgregor, Dr. L. R. Moore, Dr. F. J. North, Dr. J. Pringle, Dr. W. E. Swinton, Dr. Mabel E. Tomlinson, Dr. F. S. Wallis, Prof. D. M. S. Watson, F.R.S., Dr. T. S. Westoll, Mr. T. H. Whitehead, Prof. W. F. Whittard, Prof. S. W. Wooldridge. **£20.**

To consider and report on questions affecting the teaching of geology in schools.—Dr. A. E. Trueman, F.R.S. (*Chairman*), Dr. Mabel E. Tomlinson (*Secretary*), Prof. A. H. Cox, Mr. J. Davies, Miss Gaynor Evans, Prof. W. G. Fearnsides, F.R.S., Prof. G. Hickling, F.R.S., Prof. D. E. Innes, Prof. W. J. Pugh, Dr. A. K. Wells, Miss M. A. Arber, Dr. L. R. Moore, Prof. A. Wood.

The collection, preservation, and systematic registration of photographs of geological interest.—Prof. H. L. Hawkins, F.R.S. (*Chairman*), Mr. G. S. Sweeting (*Secretary*), Mr. H. Ashley, Dr. A. J. Bull, Mr. G. Macdonald Davies, Mr. J. F. Jackson, Dr. A. G. MacGregor, Dr. F. J. North, Dr. A. Raistrick, Mr. J. Ranson, Prof. S. H. Reynolds.

SECTION D.—ZOOLOGY.

To nominate competent naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.—Prof. H. G. Jackson (*Chairman*), Prof. J. E. Harris (*Secretary*), Prof. H. Munro Fox, F.R.S., Dr. C. F. A. Pantin, F.R.S., Mr. F. S. Russell, F.R.S., Prof. C. M. Yonge, F.R.S. **£50.**

To co-operate with other sections interested, and with the Zoological Society for the purpose of obtaining support for the Zoological Record.—Mr. M. A. C. Hinton, F.R.S. (*Chairman*), Dr. J. P. Harding (*Secretary*), Dr. I. Gordon, Mr. N. B. Kinnear, Dr. O. W. Richards. **£50.**

SECTIONS D, K.—ZOOLOGY, BOTANY

To consider the position of biology in the school curriculum and matters relating thereto.—Dr. C. F. A. Pantin, F.R.S. (*Chairman*), Mr. A. S. Gillespie, Dr. I. Gordon, Prof. R. J. D. Graham, Prof. T. M. Harris, Mr. W. J. Heasman, Dr. A. G. Lowndes, Prof. Lily Newton, Prof. A. D. Peacock, Dr. H. Hamshaw Thomas, M.B.E., F.R.S., Prof. J. Walton. **£5.** (*Secretary to be appointed.*)

To aid competent investigators selected by the committee to carry out definite pieces of work at the Freshwater Biological Station, Wray Castle, Windermere.—Prof. F. E. Fritsch, F.R.S. (*Chairman*), Mr. H. C. Gibson (*Secretary*), Prof. P. A. Buxton, F.R.S., Dr. G. S. Carter, Miss P. M. Jenkin, Prof. W. H. Pearsall, F.R.S. **£50.**

To aid competent investigators selected by the committee to carry on definite pieces of work at the Zoological Station at Naples.—Dr. C. F. A. Pantin, F.R.S. (*Chairman & Secretary*), Prof. H. Munro Fox, F.R.S., Prof. F. E. Fritsch, F.R.S., Prof. A. C. Hardy, F.R.S., Dr. Margery Knight, Prof. Lily Newton, Prof. J. Z. Young, F.R.S. **£50.**

Co-ordinating committee for Cytology and Genetics.—Prof. R. A. Fisher, F.R.S. (*Chairman*), Dr. K. Mather (*Secretary*), Prof. F. T. Brooks, C.B.E., F.R.S., Dr. D. G. Catcheside, Prof. F. A. E. Crew, F.R.S., Dr. C. D. Darlington, F.R.S., Dr. E. B. Ford, F.R.S., Dr. J. Hammond, F.R.S., Prof. T. J. Jenkin, Dr. P. C. Koller, Prof. I. Manton, Prof. L. S. Penrose, Dr. G. Pontecorvo, Dr. R. R. Race, Dr. F. W. Sansome, Dr. P. T. Thomas, Dr. W. B. Turrill, Prof. C. H. Waddington, F.R.S. **£5.**

SECTION E.—GEOGRAPHY.

To prepare a scheme for a projected National Atlas of Great Britain and Northern Ireland.—Prof. E. G. R. Taylor (*Chairman*), Prof. S. W. Wooldridge (*Secretary*), Maj.-Gen. G. Cheetham, C.B., D.S.O., M.C., Prof. H. C. Darby, Prof. F. Debenham, O.B.E., Capt. C. Diver, C.B.E., Prof. E. Estyn Evans, Prof. H. J. Fleure, F.R.S., Prof. D. L. Linton, Prof. K. Mason, Prof. A. G. Ogilvie, O.B.E., Sir Edward Salisbury, C.B.E., F.R.S., Prof. L. Dudley Stamp, C.B.E., Prof. A. G. Tansley, F.R.S., Dr. E. C. Willatts. **£10.**

To consider and report upon ambiguities and innovations in geographical terminology.—Prof. E. G. R. Taylor (*Chairman*), Mr. A. E. Smailes (*Secretary*), Prof. E. G. Bowen, Prof. W. G. East, Mr. T. W. Freeman, Mr. H. King, Mr. R. H. Kinvig, Prof. D. L. Linton, Dr. C. P. Snodgrass, Mr. A. Stevens, Prof. S. W. Wooldridge. **£5.**

To collect records of the revival of Geography in the British Isles dating from the later years of the nineteenth century.—Mr. J. N. L. Baker (*Chairman*), Mr. T. W. Freeman (*Secretary*), Prof. W. G. East, Dr. A. Geddes, Prof. D. L. Linton. **£5.**

The promotion and co-ordination of studies in the British Isles of Urban geography.—Prof. C. B. Fawcett (*Chairman*), Mr. E. W. Gilbert (*Secretary*), Mr. M. R. G. Conzen, Dr. A. Geddes, Mr. A. E. Smailes, Dr. E. C. Willatts. **£5.**

SECTIONS E, H.—GEOGRAPHY, ANTHROPOLOGY.

To collect and record information on demography and seasonal activities in relation to environment in Inter-Tropical Africa.—Prof. C. Daryll Forde (*Chairman and Secretary*), Prof. F. Debenham, O.B.E., Dr. M. Fortes, Dr. M. Gluckman, Prof. A. G. Ogilvie, O.B.E., Dr. Audrey Richards, Mr. R. W. Steel. **£5.**

SECTION H.—ANTHROPOLOGY.

To co-operate with the Torquay Natural History Society in investigating Kents Cavern.—Sir Arthur Keith, F.R.S. (*Chairman*), Mr. D. B. Harden (*Secretary*), Mr. A. Leslie Armstrong, Mr. M. C. Burkitt, Miss D. A. E. Garrod, Mr. A. D. Lacaille, Mr. A. G. Madan, Sir John Myres, O.B.E. **£5.**

To co-operate with a committee of the Royal Anthropological Institute in the exploration of caves in the Derbyshire district.—Mr. M. C. Burkitt (*Chairman*), Mr. A. Leslie Armstrong (*Secretary*), Dr. Arthur Court, Prof. H. J. Fleure, F.R.S., Miss D. A. E. Garrod, Dr. J. Wilfred Jackson, Prof. L. S. Palmer. **£37 10s.**

To report on the composition of ancient metal objects.—Prof. V. Gordon Childe (*Chairman*), Dr. C. H. Desch, F.R.S. (*Secretary*), Prof. H. J. Fleure, F.R.S., Prof. C. F. C. Hawkes, Prof. M. E. L. Mallowan, Mr. H. Maryon, Dr. A. Raistrick, Dr. R. H. Rastall.

To carry out research among the Ainu of Japan.—Mrs. C. G. Seligman (*Chairman and Secretary*), Dr. H. S. Harrison, Rt. Hon. Lord Raglan, Mr. Arthur Waley.

To report to the Sectional Committee on the question of re-editing 'Notes and Queries in Anthropology.'—Prof. H. J. Fleure, F.R.S. (*Chairman*), Mrs. C. G. Seligman (*Secretary*), Prof. W. E. le Gros Clark, F.R.S., Mr. A. Digby, Prof. E. E. Evans-Pritchard, Prof. C. Daryll Forde, Prof. J. H. Hutton, C.I.E. **£25.**

REPORT OF THE COUNCIL TO THE GENERAL COMMITTEE, 1946–7

Obituary

1. The Council have to deplore the loss by death during the past year of three past Presidents of the Association, namely Sir Thomas Holland, K.C.S.I., K.C.I.E., F.R.S. (1929), Sir Frederick Gowland Hopkins, O.M., F.R.S. (1933) and Sir James Jeans, O.M., F.R.S. (1934).

The Association was represented at the funeral of Sir James Jeans by Sir Richard Gregory, Bt., F.R.S. (then President), and at memorial services to Sir Frederick Gowland Hopkins by Sir Henry Dale, O.M., G.B.E., F.R.S. (as President) and to Sir Thomas Holland by Professor David Brunt, F.R.S. (past General Secretary).

The Association has also suffered the loss of the following office bearers and supporters :—

Lady Avebury
Sir Joseph Barcroft, C.B.E., F.R.S.
Prof. B. H. Bentley
Dr. F. F. Blackman, F.R.S.
Dr. S. Monckton Copeman, F.R.S.
Sir John Flett, K.B.E., F.R.S.
Dr. P. F. Frankland, F.R.S.
Mr. A. L. Howard
Councillor A. B. Lister
Prof. B. A. McSwiney, F.R.S.
Mr. W. H. Blyth Martin, C.B.E.
Dr. C. S. Myers, C.B.E., F.R.S.
Mr. H. J. E. Peake
Prof. H. C. Plummer, F.R.S.
Prof. P. M. Roxby
Dr. Alexander Scott, F.R.S.
Mr. H. G. Wells, D.Litt.
Brig. H. S. L. Winterbotham, C.B., C.M.G.
Principal H. A. S. Wortley.

The Association was represented at a memorial service to Professor B. A. McSwiney (a member of Council) by the President, Sir Henry Dale. In collaboration with representatives of other bodies, the Secretary organised a tribute meeting to Mr. H. G. Wells, which was held in the Royal Institution and at which Sir Richard Gregory, then President, was one of the speakers.

Relations with other Institutions

2. Representatives of the Association were appointed by the Council as follows :—

Service of Intercession for the United Nations at St. Paul's. Professor Allan Ferguson.

Conference on 'Whither Civilisation' organised by the Institute of Sociology. Prof. H. D. Kay, C.B.E., F.R.S.

Conference on 'Science and Education' organised by the Association of Scientific Workers. Mr. James Kendall.

Annual Meeting of the French Association for the Advancement of Science at Nice, 1946. Dr. Edward Hindle, F.R.S., and Prof. H. Munro Fox, F.R.S.

Annual Meeting of the Australian and New Zealand Association for the Advancement of Science at Adelaide, 1946. Sir John Madsen.

Laboratory Porcelain Committee of the British Standards Institution. Dr. R. Lessing.

Annual Meeting of the Indian Science Congress Association at Delhi, 1947. Sir Charles Darwin, K.B.E., F.R.S., Sir Arthur Fleming, C.B.E., Prof. H. Munro Fox, F.R.S., and Prof. L. Dudley Stamp, C.B.E., who, with representatives of the Royal Society, formed a delegation from the U.K.

Centenary Celebrations of the Institution of Mechanical Engineers. Dr. R. V. Southwell, F.R.S.

Annual Meeting of the American Association for the Advancement of Science, Boston, 1946. Professor C. B. Fawcett, Prof. J. B. S. Haldane, F.R.S., and Prof. D. M. S. Watson, F.R.S.

Centenary Dinner of the Palæontographical Society. Sir Henry Dale, O.M., G.B.E., F.R.S.

Council for the Promotion of Field Studies. Prof. W. H. Pearsall, F.R.S.

XIth International Congress of Pure and Applied Chemistry, 1947. Dr. J. L. Simonsen, F.R.S.

Discussion on the Promotion of International Nature Reserves. Dr. Edward Hindle, F.R.S.

Conference arranged by the Royal Society of Arts to consider the prospects of an International Exhibition in 1951. The Secretary.

Centenary Celebrations of the Educational Institute of Scotland. Prof. F. A. E. Crew, F.R.S., and Mr. Neil S. Snodgrass, F.E.I.S.

Annual Meeting of the American Academy of Political and Social Sciences, Philadelphia. Prof. C. B. Fawcett.

International Geological Congress, London, 1948 (to be appointed).

Annual Meeting of the French Association for the Advancement of Science, Biarritz, 1947. Dr. Edward Hindle, F.R.S.

Annual Meeting of the Australian and New Zealand Association for the Advancement of Science, Perth, 1947. Dr. M. M. Chattaway.

3. The Council, through its Officers and Members, have maintained contact with all scientific and cultural organisations in correspondence with the Association during the war and have made fresh contacts with others. In particular, the relationships with Associations for the Advancement of Science in other countries have been strengthened: with Australia, New Zealand, South Africa and Canada, through the presence of representatives at the Empire Scientific Conference in London and in other ways; with India through visits of officers from India to London and the presence of our delegation to Delhi; with France through the renewal of delegations to Annual Meetings. Renewal of warm co-operation with the American Association has been established with the resumption of the British-American Association exchange lecture: Professor C. B. Fawcett lectured to the American Association, meeting at Boston, on The Numbers and Distribution of Mankind, and the Association will welcome Dr. Kirtley F. Mather at the Dundee Meeting. The Council hopes that a proposal to arrange a joint meeting between the two Associations in Canada may not be impracticable at an early date.

The Council have received reports on the development of U.N.E.S.C.O., and are co-operating in this great international venture. Dr. Edward Hindle, F.R.S., and Dr. O. J. R. Howarth, O.B.E., have been appointed members of the British Committee for Co-operation in the Natural Sciences, and Professor H. R. Hewer has been nominated by the Council as a member of the Film Panel of the Co-operating Body for Mass Media.

Having no meeting rooms of its own, the Association is indebted to the Royal Society, the Royal Institution, the Geological Society, the Institution of Civil Engineers, and the Institute of British Architects for meetings held during the year.

Finance

4. The General Treasurer's Statement and Account for the financial year ending March 31, 1947, will be submitted to the General Committee.

Officers and Council

5. *President, 1948.*—The Council's nomination to the office of President of the Association for the year 1948 will be submitted at Dundee.

6. *General Officers, 1947–48.*—The Council have learned with much regret that Sir John Lennard-Jones is unable to offer himself for re-election as a General Secretary and nominate the following:—

General Treasurer: Mr. M. G. Bennett.

General Secretaries: Dr. Edward Hindle, F.R.S., and Dr. R. V. Southwell, F.R.S.

7. *Honorary Auditors, 1947–48.*—The Council nominate Dr. Ezer Griffiths, F.R.S., and Mr. R. S. Whipple.

8. *Ordinary Members of Council.*—The Council have lost from their membership Prof. B. A. McSwiney by death and Sir John Fryer and Prof. H. R. Robinson by retirement and have appointed in their stead Prof. Winifred Cullis, Prof. R. G. White and Sir Edward Appleton respectively.

The members retiring under Statute III, 3, are: Sir Fred Clarke, Prof. F. E. Fritsch, F.R.S., Prof. C. A. Mace, Prof. J. G. Smith and Sir Henry Tizard, K.C.B., F.R.S.

The Council have nominated as new members Wing Commander T. R. Cave-Browne-Cave, C.B.E., Dr. K. G. Fenelon and Mr. James Hornell; leaving two vacancies to be filled by the General Committee without nomination by the Council. If the Council's nominations are approved, the two remaining places on the Council should be filled by representatives of Sections J (Psychology) and K (Botany).

The full list of nominations of Ordinary Members is as follows:—

Sir Edward Appleton, G.B.E., K.C.B., F.R.S.
Prof. F. C. Bartlett, C.B.E., F.R.S.
Prof. J. D. Bernal, F.R.S.
Prof. D. Burns
P. Ritchie Calder, C.B.E.
Wing Commdr. T. R. Cave-Browne-Cave, C.B.E.
Prof. W. E. Le Gros Clark, F.R.S.
Prof. Winifred Cullis, C.B.E.
Dr. C. D. Darlington, F.R.S.
Sir Charles Darwin, K.B.E., F.R.S.
Dr. H. J. T. Ellingham
Prof. C. B. Fawcett
Dr. K. G. Fenelon
Sir Arthur Fleming, C.B.E.
Prof. H. J. Fleure, F.R.S.
Dr. J. C. Maxwell Garnett, C.B.E.
R. F. Harrod
James Hornell
Dr. O. J. R. Howarth, O.B.E.
Sir John Graham Kerr, F.R.S., M.P.
Prof. J. W. Munro
Prof. E. H. Neville
Dr. W. G. Ogg
Prof. H. H. Read, F.R.S.
Dr. J. L. Simonsen, F.R.S.
Dr. R. V. Southwell, F.R.S.[1]
Dr. C. J. Stubblefield, F.R.S.
Prof. R. G. White

[1] Subject to appointment as a General Secretary.

General Committee

9. The following have been admitted as members of the General Committee on the nomination of Sectional Committees :—

Section A : Prof. H. Dingle.
Section B : Prof. H. W. Melville, F.R.S.
Section D : Prof. J. E. Harris, Prof. H. Munro Fox, F.R.S., Prof. J. Z. Young, F.R.S.
Section F : Dr. J. A. Bowie, Mr. J. K. Eastham.
Section H : Mr. J. Hornell, Prof. E. O. James.

Honorary Membership

10. In accordance with Statute XII, 3, the Council nominate Dr. O. J. R. Howarth, O.B.E., lately Secretary of the Association and now Honorary Curator of Down House, for election as an Honorary Member.

Amendment to Regulations

11. In accordance with Regulation 29, the Council has approved and brought into operation amendments to Regulation 19 which modify the authority of the General Treasurer to defray travelling and other expenses. The amendments are shown in Appendix I and are submitted to the General Committee for approval and confirmation.

Conferences

12. Three Conferences have been held during the year under review.

On July 25, 1946, by collaboration between the Division for the Social and International Relations of Science and Section L (Education), a Conference was held in the hall of the Royal Institute of British Architects on 'U.N.E.S.C.O. and the Universities.'

On September 12–13, 1946, in the rooms of the Institution of Civil Engineers, Section G (Engineering) with collaboration from the Division, held a Conference on 'London Traffic and the London Plan.'

Reports of these Conferences have been published in *The Advancement of Science.*

On May 10, 1947, in the University of Manchester, the Division held a Conference on 'The Place of Universities in the Community,' which will be reported in *The Advancement of Science.* The Council received from this Conference two resolutions—when the following action was taken :—

Resolution : This Conference, recognising the great responsibility devolving upon the Universities because of their key position in the life of the Community, recommends to the Council of the British Association that the University Grants Committee be invited, in collaboration with the Universities—

(i) to make extensive factual surveys of the openings for graduates in the national life,
(ii) to maintain records of the careers of University graduates and the measure of their success in their professions,
(iii) to publish periodic reports of the result of such surveys for the guidance of Universities and schools.

Action. Approved for discussion with the University Grants Committee.

Resolution : This Conference recommends to the Council of the British Association that they should make representations to the competent authorities of all Universities of the British Empire urging that no contract for research should normally be accepted by the Scientific Departments of any of these Universities if its terms include any restriction on freedom of publication.

Action. Approved for communication to the Universities of the Commonwealth and Empire.

Lectures

13. The Association maintains three memorial lectures, all of which fell due to be delivered in the year under review. The Council appointed speakers who delivered their lectures as follows :—

Norman Lockyer Lecture

Dundee, Caird Hall, April 10, 1947, Sir Robert Watson-Watt, C.B., F.R.S., on 'Radar in War and Peace.'

Radford Mather Lecture

Cambridge, Arts School, May 2, 1947, Sir Howard Florey, F.R.S., on 'Penicillin and other Antibiotics.'

Alexander Pedler Lecture.

London, Royal Institution, May 14, Professor E. D. Adrian, O.M., F.R.S., on 'The Sense of Smell.'

Research

14. Subject to certain conditions the Council have authorised the payment of the following grants from the funds under their control :—

Committee.	*Grant.* £	*Fund charged.*
Seismological Investigations	100	Caird Fund
Plymouth Marine Laboratory	50	" "
Naples Zoological Station .	50	" "
'Zoological Record'. .	50	" "
Mathematical Tables .	80	" "
" " .	50	Cunningham Fund
Geological Photographs .	100	Hobson Fund
Kent's Cavern . .	5	" "
Freshwater Biological Station	75	Musgrave Fund

Council has also ordered the reservation of £930 (to be borne on the Mathematical Tables Fund and the Grants Equalisation Fund) for the estimated cost of printing the Mathematical Tables Committee's second volume of Bessel Functions.

Miss E. J. Hanson has been granted temporary use of the Association's table at Naples, and Dr. Otto Lowenstein, of the table at Plymouth Laboratory.

Following the transfer of seismological investigations from Oxford University Observatory, the Council approved a recommendation by the Seismology Committee that the Association's instruments and library be moved to Down House.

As regards Mathematical Tables, the Council, after consultation with the Mathematical Tables Committee, are endeavouring to arrange that future developments in this field will be supported on a scale worthy of the programme which the Committee has drawn up.

Publications

15. The Council is indebted to the Royal Society for allocating £500 from the Government Grant for Publications.

It has been possible to produce only two numbers of *The Advancement of Science* during the year : a third, containing the texts of the Presidential Addresses at Dundee will be prepared by the time of the Meeting.

With the assistance of an Advisory Committee the Council has reviewed the Association's Publications, and action has been taken or is contemplated as indicated in Appendix II.

Down House

16. The number of visitors to Down House in 1946 was 3,448, and there is at present (June, 1947) no sign of a larger number during the current year. The annual average number before the war was 7,000. There are certain reasons to account for the decrease. No attempt has been made to advertise the house by paid announcements. The transport authorities have not revived the posters and other sources of information which before the war drew public attention to the house. It is probable that some of the guide-books which mentioned the house have not yet been reissued since the war. A substantial proportion of the visitors has always consisted of passers-by, who see the inscription at the gate, and come in. Since the war there has never (save perhaps at Whitsun, 1947) been any approach to the large numbers of people who, on foot and in cars, used to visit this part of the countryside.

This reduction in the number of visitors may not be permanent ; but in the meantime it strengthens the sentiment showed by many, that the property ought to be put to scientific uses in greater measure than it is now. Various possibilities which have been discussed have not materialised, but the idea is ever present in the minds of those concerned with the maintenance of the house. Meanwhile the reading of the official rain-gauge has been maintained, and the precipitation in 1947 measured 39·41 inches, nearly 10 inches in excess of the average on the nine preceding years. The station has also made returns to a recent organisation for observations of snowfall. The experimental bed of *Lythrum salicaria* (purple loosestrife) has been maintained by Professor R. A. Fisher, F.R.S., and Dr. K. Mather, as noted in previous reports. During the present year the Seismological Library, the basis of which is the collection bequeathed by John Milne to the British Association, has been moved from the University Observatory at Oxford to Down House. So also have the two Milne-Shaw seismographs belonging to the Association, which had been operated at Oxford. These instruments have been erected on a suitable base in the cellar of the house, and are now under test with a view to establishing a regular series of observations.

Repairs and redecoration are carried on, by the house staff, as opportunity offers : the process is necessarily slow, and parts of the house are in very poor state, but in present conditions there is no means of expediting the work.

Suggestions have been made as to the possibility of disposing of some of the land which did not belong to Darwin, especially that portion which was bought by the Association with a view to averting the building of bungalows some fifteen years ago. No demand, however, has as yet appeared for the use of any of the land for commercial horticulture ; and as for building, the planning of the whole area has recently been completely changed, and none of it is now scheduled for possible building, excepting a small area beyond our bounds and immediately adjacent to Downe village. Our own property is treated as green belt land.

Future Policy

17. The Council present the following statement on their policy :—

(*a*) Since the meeting of the General Committee on July 20, 1946, the Officers and Council have given much attention to the future pattern of the Association's work and have welcomed the guidance and assistance of a sub-committee appointed to advise on the problem.

(*b*) The objects of the Association are—

(i) To give a stronger impulse and a more systematic direction to scientific enquiry ;

(ii) To promote the intercourse of those who cultivate science in different parts of the Empire with one another and with foreign philosophers ;

(iii) To obtain more general attention for the objects of science ;

(iv) To obtain the removal of any disadvantages of a public kind which impede the progress of science.

(*c*) *To stimulate and direct Scientific enquiry.*

The time has no doubt passed when the Association can expect to play any spectacular part in the advancement of science by original research. In recent years the endowment of research has increased to a degree which makes the sums of money available to the Association for financing research relatively insignificant. In this field, however, the Association still has a number of important functions which should be pursued with zeal. By virtue of the wide field covered by its constitution and the opportunities which its meetings afford for discussion, the Association is eminently qualified—

(i) To appoint committees to study general problems, particularly where more than one branch of science is concerned ;

(ii) To identify or select problems on which research is required, and to move the appropriate authorities to take action ;

(iii) To assist, with relatively small grants of money, research which might otherwise not be undertaken. At a time when funds may be more readily made available from other sources for teams of scientific workers, the Association should continue to encourage individual workers who may not have access to funds available for research. It is not, however, contemplated that the Association should maintain such work, and the maximum of five annual grants, recently adopted by the General Committee, implies that, if the work is not completed in that period, it should have qualified for aid from other sources.

(*d*) *To promote intercourse between scientists at home and abroad.*

Through its meetings the Association provides opportunities for intercourse between scientists, mainly on a national scale, occasionally on an international scale when overseas guests are entertained at annual meetings ; representatives are appointed whenever possible to attend meetings of other organisations at home and overseas ; relations with scientific societies abroad have been maintained throughout the war and the contacts are particularly close and friendly with kindred Associations in other countries which were founded on the model of the British Association. The Association is hampered in this field for lack of money, though there is the merest nucleus of a fund which was established before the war to assist with the cost of overseas delegations. The development of such a fund must be regarded as one of the long-term objectives of the Association, and in the meantime it is proposed that in so far as finance is required for these purposes, the Association should submit claims to the Royal Society, the British Council, and any other bodies which administer grants for these objects.

(*e*) *To obtain the removal of disadvantages impeding the progress of science.*

The Association will continue to draw attention to any impediments of a public kind which hinder the progress of Science, and the Council will continue to give sympathetic consideration to any resolutions which may be sent forward by the Sections, the Division, or the Conference of Delegates.

(*f*) *To obtain more general attention for the objects of science.*

This has been, and still is, the chief function of the Association.

The Annual Meeting.—The principal medium has hitherto been the annual meeting, though the Association has contrived in other ways to disseminate information about science. There has never been agreement whether the main object of the annual meeting was to provide a public platform or to provide scientists of different disciplines with opportunities of meeting. By the guidance given to Sectional Committees in drafting their programmes for the Dundee Meeting, the Council has recognised the important opportunity these meetings provide of acquainting the layman with the progress of science. While specialism has not been banished, the emphasis has been laid on communications of a general nature, intelligible to the layman. Unlike many learned societies the Association has a high percentage of laymen among its subscribers and so long as the annual meeting remains the main source of recruitment of members, the Association must cater for the needs of the layman.

Annual Meetings have hitherto been financed partly from the funds of the Association, partly from funds raised in the

locality. Local funds were of the order of £2,500 before the war, and it should be an object of the Association to relieve host cities of such a heavy burden.

The Division for Social and International Relations of Science.—Meetings of the Division can be, and are, held separately from the annual meeting and should be continued. It should probably be considered in the near future whether the word 'International' now has any particular significance. The terms of reference of the Division were drafted before there was any such organisation as U.N.E.S.C.O., and ought to be revised in the light of the development of that organisation.

Meetings of the Division are not run without expense, and funds are required to organise them successfully.

Public Lectures.—The Association maintains three memorial lectures, two annual and one triennial, which are open to the public ; and public lectures are normally arranged at the time of the annual meeting. The Association could no doubt extend this public service, particularly in the provinces, and this is one of the questions which will be considered by the Conference of Delegates of Corresponding Societies.

Publications.—The Advancement of Science, which will appear quarterly in future, is the main organ of the Association, and there are other occasional publications. It has been suggested that the Association might embark on a more popular periodical which would reach a wide public and command regular subscriptions from many who would not attend the annual meeting. The Publications Advisory Committee has considered this, and has recommended that, while the project should remain under consideration, the present is not an opportune time for taking such a step, and every endeavour should be made in the meantime to adapt *The Advancement of Science* to the requirements of a wide reading public. The Council has approved a scheme for a British Association *Year Book of Science*.

Information Bureau.—The Council, advised by a sub-committee, have given considerable attention to the proposal that a Bureau of Scientific Information should be established. The Council has so far been unable to agree that such a Bureau should be set up, the main difficulties being the cost of staff, premises and equipment for carrying out the programme envisaged, and some doubts as to the need for all the functions assigned to the Bureau. By virtue of its constitution and record, the Association is eminently qualified to undertake the responsibility of supplementing and co-ordinating such services as at present exist for disseminating scientific information to the public. The Association accepts the responsibility for undertaking any additional services which may be required, and in the meantime further information on existing services is being collected, and the Association is in touch with U.N.E.S.C.O., which proposes to promote scientific information bureaux in member countries.

(*g*) *Regional activity.*

One post-war aim has been suggested, namely ; that the Association should extend and develop its relations with scientific societies in this country, particularly in the provinces, with a view to the ultimate establishment of a regional organisation. It is hoped that a beginning will be made in the study of this possibility at the Dundee Meeting when the Conference of Delegates of Corresponding Societies will discuss the scope for further collaboration with each other and with the Association.

(*h*) *The Place of youth in the Association.*

The appointment of student exhibitioners has been renewed and should be maintained. The Sections have been recommended to give as much scope as possible to young workers to read papers at meetings and to discuss their work with their elders. It has been suggested, in addition, that annual summer camps should be organised for young people either at the time of or apart from the annual meetings. The Officers regard this proposal as something which will need further consideration in the light of the Association's financial position after the Dundee Meeting.

(*i*) *Down House.*

The Association maintains Down House as a national memorial to Charles Darwin. Owing to rising maintenance costs and falling income from investments, there is a gap between expenditure and income which is reaching the order of £900 per annum which has to be found from general income. This is a gap which cannot be closed by further economies, and the drain on the resources of the Association is a burden which cannot continue to be borne without restricting the effectiveness of the Association in other directions. The only possible solution appears to be an appeal for further endowment of the order of £40,000 to £50,000.

(*j*) *Staff and Office accommodation.*

The Association is indebted to many scores of voluntary officers and other helpers, but needs a strong paid secretariat with appropriate office accommodation.

As regards staff the pre-war complement was five. During nine nonths of the year ending March 31 last there were only three people in the office. During twelve months from June 1, 1946, outgoing communications numbered approximately 25,000, an average of 2,000 a month. Keeping the position under review the General Officers authorised the appointment of an additional typist in March, and filled the vacant post of Assistant Secretary as from July 1.

As regards office accommodation, it is generally agreed that the position is deplorable. The office consists of three rooms in Burlington House, where the Association is the guest of the Government. Owing to the preoccupation of the Government it does not appear to be likely that any immediate steps will be taken to improve the accommodation of learned societies in general or any one particular, and the inescapable conclusion seems to be that the Association should appeal for contributions to a Building Fund.

(*k*) *Conclusion.*

The Council are convinced that, given the means, the Association has a great future before it. They take the view that the means should be provided, in the main, from membership subscriptions. To this end they regard the success of the annual meetings, particularly the Dundee Meeting, as indispensable.

The next step should be to consolidate the position by maintaining the interest of subscribers by every possible means, such as more frequent and more attractive publications, in order to secure as regular members those who would otherwise subscribe for one year only. The Association should aim at increasing the number of subscribers over the next ten years to a figure of not less than 10,000. If this could be done, and if a journal could be established with a circulation of this magnitude, the finances of the Association might be placed on a more secure foundation than exists at present.

With an assured income the Association could extend its activities with some confidence. An information service could be established on a scale not now possible. A larger headquarters staff could be provided and better accommodation secured. More student exhibitions could be awarded and the interests of youth enlisted by a variety of means.

It is not suggested that these proposed activities should await the full attainment of the membership proposed. They could be developed *pari passu* with the increase in membership and the growth in financial strength of the Association. The central problem of the Association is one of finance; and the range of its activities and the extent of its future success depend on the adequate solution of this problem.

Two items, however, cannot wait for a long-term increase in income, namely the proper endowment of Down House and the provision of adequate office accommodation, and the Council have authorised the preparation of appeals.

Appendix I

Regulation 19 as approved by General Committee in January 1946.

Finance

Travelling Expenses, etc.

19. The General Treasurer shall be authorised, subject to approval, and within limitations defined, by the Council, to defray travelling and other expenses as follows :—

(i) Fares and postages incurred by the President and General Officers in connection with the Annual Meeting, the meetings of the Council, and other meetings involved by the discharge of their official duties.

(ii) Fares incurred by Members of the Council in attending meetings thereof.

(iii) Fares and subsistence expenses incurred by members of the Staff in connection with attendance at the Annual Meeting and otherwise in the discharge of their duties.

Regulation 19 as amended : submitted to General Committee for endorsement.

Finance

Travelling Expenses, etc.

19. The General Treasurer shall be authorised to defray travelling and other expenses as follows :—

(i) Fares, postages and other necessary expenses incurred by the President, General Officers and Chairman of Council in connection with the Annual Meeting, the meetings of the Council, and other meetings involved by the discharge of their official duties.

(ii) Fares incurred by Members of the Council in attending meetings thereof.

(iii) Fares and subsistence expenses incurred by members of the Staff in the discharge of their duties.

(iv) Fares incurred by Recorders and Secretaries of Sections in connection with attendance at the Annual Meetings and meetings of the Sectional Committees.

(v) Postages and essential clerical expenses incurred by the Recorders or their Sectional Secretaries on their behalf) in the discharging of their duties, provided that no claim exceeding £10 under this heading by any Recorder in any one year shall be allowed without the express sanction of the Council.

It shall be competent for the Council, if they think desirable, to authorise payments in respect of travelling expenses to Members appointed by them to represent the Association at meetings of other bodies, for which formal invitation has been received.

(iv) Fares incurred by Recorders and Secretaries of Sections in connection with attendance at the Annual Meetings and meetings of the Sectional Committees.

(v) Postages and essential clerical expenses incurred by the Recorders (or their Sectional Secretaries on their behalf) in the discharge of their duties, provided that no claim exceeding £10 under this heading by any Recorder in any one year shall be allowed without the express sanction of the Council.

(vi) Travelling expenses of Members appointed by the Council to represent the Association at meetings of other bodies, for which formal invitation has been received.

Appendix II

Publications

In December 1946 the Council appointed a Publications Advisory Committee consisting of Prof. L. Dudley Stamp, C.B.E. (Chairman), Mr. Ritchie Calder, C.B.E., Sir Richard Gregory, Bt., F.R.S., Dr. O. J. R. Howarth, O.B.E., and the Officers of Council *ex officio*.

This Committee reviewed the policy of the Association in regard to publications and printing generally and submitted a report in June which was approved by the Council. The following are the principal recommendations:—

(i) That the Presidential Address and the Sectional Presidential Addresses should be printed before the Meeting, each President to receive, if desired, one hundred copies free of charge, as laid down in the Regulations (No. 21).

(ii) That the Presidential Address and the Sectional Presidential Addresses be bound together as one number of *The Advancement of Science*, to be available for sale at the Meeting in Dundee.

(iii) That no Journal (containing abstracts of papers) be printed this year.

(iv) That abstracts be collected as usual from authors of papers for use of the Sectional Officers and the Press, duplicated copies being made available as required in the Press Bureau and in the Section meeting-rooms.

(v) That a definite effort be made to publish a permanent record of the more important of the proceedings at the Annual Meeting, *The Advancement of Science* to contain—

(*a*) A general account of the week's activities.

(*b*) Full reports of papers and discussions *recommended by the Sections for publication*

(vi) That, in the absence of the Journal (which gave information about papers arranged Section by Section), the Programme of the Meeting should contain two Sections: one which gives a list of items Section by Section and another which gives day by day and hour by hour (indicating the Sections) a list of the items *which are indicated by Sections* as being of general interest.

(vii) That a printed list of members should not be presented to each member attending the Meeting provided that arrangements were made for such information to be made available in the Reception Room, in the Section Rooms, and in the Press Bureau.

(viii) That, subject to finance, offprints of the General Account of the Meeting, (v) (*a*) above, should be supplied free of further charge to all who attend the meeting.

(ix) That, by arrangement with the Editors of *Nature*, offprints of summaries of the Presidential Addresses, prepared before the meeting, should be presented to all who attend the meeting.

(x) That, while the advantages of a new semi-popular scientific periodical should not be overlooked, and the matter should be kept under review, the Association should not, at this stage, consider the publication of such a periodical.

(xi) That *The Advancement of Science*, while remaining the official organ of the Association, should be so edited as to appeal to as wide a public as possible.

(xii) That the Council should make arrangements for the publication of a British Association *Year Book*.

(xiii) That arrangements should be made to consider, after the Dundee Meeting, the scope for occasional publications such as *The March of Science* (a quinquennial review published for the Association by Pitman in 1935 and since lapsed) and reprints of articles from *The Advancement of Science*.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

GENERAL TREASURER'S STATEMENT AND ACCOUNT, 1946–47

THE Association's financial year to March 31, 1947, for which the Balance Sheet and Accounts are here presented, is the last of a series of seven years during which no full-scale meeting of the Members has been held. We may congratulate ourselves on emerging from these difficult years as well as we have. Nevertheless, it is important that Members should appreciate that the war has left us, in common with many other Institutions, with rising costs and reduced income from investments to such an extent that there is an adverse balance on the two main sections of the Accounts, namely, the General Account and the Down House Account. How the gaps in these Accounts can be bridged is a matter which is receiving the active consideration of the Council, and in this connection the support for the first full post-war meeting at Dundee is a crucial consideration.

A legacy has been received of £1,000 for general purposes under the will of the late Dr. F. W. Aston, F.R.S., and a gift of £100 for research in memory of the late Miss J. R. Corcoran. The Association acknowledges these sums with great gratitude.

The Balance Sheet shows that the realisation by redemption of certain stocks has brought some capital profit into account, but at the same time the income has fallen. Thus, the repayment of £4,185 Local Loans 3 per cent. Stock gave a capital profit of £1,111 on the original purchase price of £3,074, but the interest on the new investment in 2½ per cent. Treasury Stock will be £21 a year less than it was on the Local Loans.

As regards Membership, and the increase in the subscription, the full effect will not be discerned until after the Dundee Meeting. It is interesting to note, however, that income from Members' and Associates' subscriptions increased from £322 by £515 to £837 compared with last year. This increase must be put down mainly to a reviving interest in the Association, and there is no evidence that any potential Members may have been deterred by the increase in subscription which has operated during the year under review. It seems right that our additional costs should be met very largely out of current income in this way.

With reference to the figure of £911, which is a final contribution from the Yarrow Fund, it will be recalled that the late Sir Alfred Yarrow, in making his gift of £10,000 to the Association in 1926, attached the condition that it should be wholly expended within approximately twenty years, submitting among his reasons for doing so his belief that 'each generation should look after itself.' By this fund the Association has, during the last twenty years, been enabled to operate on a larger scale than would otherwise have been possible, and it is fitting that Sir Alfred Yarrow's liberality should be remembered in any review of the Association's work during the term of the gift.

The brightest part of the picture is the accumulated unspent income from the special research and other similar funds. This amounts to some £860. The reason for the accumulation is, of course, again the war, and now that the tempo of activity is increasing so is the call upon these funds. During the year there was a net excess of expenditure over income of £120 which was drawn from the accumulated balance. Some of this excess may be recovered from the sale of Mathematical Tables ; but these figures demonstrate the wisdom of Council's decision to limit the period of grant to any one research to five years.

The Down House Account shows a deficit of £474 after bringing in £152 from the Property Rehabilitation Fund which is now exhausted. It is calculated that further rises in wages and other expenses, together with further reductions in income from investments, will result in a deficit of about £900 per annum. The Council is making a big effort to try to solve this difficult problem. It would like to see Down House put to some service in the advancement of science which could take the burden of this load on the Association's finances. A special Committee is considering the problem in all its aspects. The custody of Down House is an honourable trust in which it would be grievous to fail.

Despite the adverse balance in our General Account, which may be said to be due to an intentional revival of activity ahead of the revival of membership, the outlook for the future is, as far as one can see, good. The signs of enthusiasm for the Dundee Meeting are encouraging and give reason to expect that, if the one problem of Down House can be solved, the future success of the Association is assured and the great services which it has always rendered to Science will not be interrupted.

M. G. BENNETT,
General Treasurer.

Balance Sheet, 31st March, 1947

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

LIABILITIES

	£ s. d.	£ s. d.
GENERAL PURPOSES :—		
Sundry Creditors	362 4 3	
Amounts received in advance for publications	222 13 8	
Membership and Associateship subscriptions in advance	123 9 0	
		708 6 11
Hon. Sir Charles Parsons' gift, 1922 (£10,000) and legacy, 1934 (£2,000)		12,000 0 0
Sir Alfred Ewing's legacy (1935)		500 0 0
Dr. C. D. Sherborn's legacy (1943)		500 0 0
Lady Mary Lockyer's legacy (1944)		1,000 0 0
British Science Guild : Capital Fund (1936)		3,431 9 1
Dr. F. W. Aston's legacy (1946)		1,000 0 0
Accumulated Fund		
As per last Account	19,145 13 8	
Add Balance transferred from Pension Fund	67 14 4	
		19,213 8 0
Yarrow Fund		
As per last Account	855 9 2	
Add Profit on transfer of stock	55 12 1	
	911 1 3	
Less Transferred to Income and Expenditure Account under terms of gift	911 1 3	
		– – –
Life and Corporation Membership Compositions		
As per last Account	4,507 2 0	
Add Subscriptions received during year	168 0 0	
Profit on redemption of investment stock	1,026 0 2	
	5,701 2 2	
Less Transferred to Income and Expenditure Account	66 0 0	
		5,635 2 2
Grants Equalisation Fund		
As per last Account	2,000 0 0	
Add Profit on redemption of investment stock	85 5 10	
		2,085 5 10

Note.—Reservation of £930, for the printing of a second volume of tables of Bessel functions prepared by the Mathmatical Tables Committee, has been authorised by the Council. The Grants Equalisation Fund and the Mathmatical Tables Fund (see below) will be drawn on for this purpose when the expenditure is incurred.

Contingency Fund		
As per last Account	1,977 3 11	
Less Excess of Expenditure over Income for the year, on General Account	320 1 2	
		1,657 2 9
Overseas Delegations Fund		781 3 11
Dr. Howarth's Pension Fund		
As per last Account	2,240 5 7	
Add Income from Investment	32 5 0	
Profit on sale of Stock	97 3 9	
	2,369 14 4	
Less Cost of Annuity . 2,302 0 0		
Balance transferred to Accumulated Fund . . . 67 14 4		
	2,369 14 4	
		– – –
[*49,064 10 11*]		48,511 18 8
SPECIAL PURPOSES :—		
Caird Fund		
Capital as per last Account	9,928 17 9	
Revenue balance as per last Account . 666 6 9		
Less Excess of Expenditure over Income for the year . . 229 19 11		
	436 6 10	
[*10,595 4 6*]		10,365 4 7
Mathematical Tables Fund		
As per last Account	208 2 3	
Add Receipts from sales	43 3 6	
[*208 2 3*]		251 5 9
[*59,867 17 8*] Carried forward		59,128 9 0

ASSETS

	£ s. d.	£ s. d.
GENERAL PURPOSES :—		
Investments as scheduled with Income and Expenditure Account, No. 1	47,779 13 9	
Sundry debtors and payments in advance	14 14 3	
Cash at bank	708 12 4	
Cash in hand	8 18 4	
[*49,064 10 11*]		48,511 18 8
SPECIAL PURPOSES :—		
Caird Fund		
Investments (see Income and Expenditure Account, No. 2)	9,928 17 9	
Cash at bank	436 6 10	
[*10,595 4 6*]		10,365 4 7
Mathematical Tables Fund		
Cash at bank		251 5 9
[*208 2 3*]		
[*59,867 17 8*] Carried forward		59,128 9 0

Balance Sheet, 31st March, 1947 (*continued*)

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

LIABILITIES (*continued*)

		£ s. d.	£ s. d.
[59,867 17 8]	Brought forward		59,128 9 0
	Cunningham Bequest Fund		
	As per last Account	1,449 13 2	
	Add Income for the year	66 11 9	
	Profit on redemption of Investment stock	365 11 3	
[1,499 13 2]			1,931 16 2
	Toronto University Presentation Fund		
	Capital	178 11 4	
	Revenue balance as per last Account . . 28 17 6		
	Add Income for the year 6 2 6		
		35 0 0	
[207 8 10]			213 11 4
	Bernard Hobson Fund		
	Capital as per last Account	1,000 0 0	
	Add Profit on redemption of investment stock	93 2 6	
		1,093 2 6	
	Revenue balance as per last Account . . 231 19 0		
	Less Excess of Expenditure over Income for the year . . . 61 7 4		
		170 11 8	
[1,231 19 0]			1,263 14 2
	Leicester and Leicestershire Fund, 1933		
	Capital	1,000 0 0	
	Revenue balance as per last Account . . 40 5 0		
	Add Income for the year 34 4 2		
		74 9 2	
[1,040 5 0]			1,074 9 2
	Property Rehabilitation Fund		
	Balance as per last Account	144 0 0	
	Add Profit on transfer of stock	5 9 11	
		149 9 11	
	Less Excess of Expenditure over Income for the year	149 9 11	
[144 0 0]			– – –
	Radford Mather Lecture Fund		
	Capital	250 0 0	
	Revenue balance as per last Account . . 36 17 11		
	Add Income for the year 7 9 4		
		44 7 3	
[286 17 11]			294 7 3
	Mrs. E. M. Musgrave's Legacy (1944)		
	Balance as per last Account	150 0 0	
	Less Expenditure for the year	75 0 0	
[150 0 0]			75 0 0
	Arthur Haydock Bequest (1945)		
	Capital	2,215 12 0	
	Revenue balance as per Last Account . . 18 5 9		
	Add Income for the year 56 13 10		
		74 19 7	
[2,233 17 9]			2,290 11 7
	Gift for research in memory of Miss J. R. Corcoran		100 0 0
[Nil]			
	Down House		
	Endowment Fund balance as per last Account	21,296 9 5	
	Library Fund	10 10 0	
	Sundry Creditors	3 7 8	
	Cash overdrawn at bank	382 19 9	
[21,542 5 6]			21,693 6 10
[88,204 4 11]			£88,065 5 6

ASSETS (*continued*)

		£ s. d.	£ s. d.
[59,867 17 8]	Brought forward		59,128 9 0
	Cunningham Bequest Fund		
	Investments (see Income and Expenditure Account, No. 3)	1,756 3 7	
	Cash at bank	175 12 7	
[1,499 13 2]			1,931 16 2
	Toronto University Presentation Fund		
	Investment (see Income and Expenditure Account, No. 4)	178 11 4	
	Cash at bank	35 0 0	
[207 8 10]			213 11 4
	Bernard Hobson Fund		
	Investments (see Income and Expenditure Account, No. 5)	1,243 2 6	
	Cash at bank	20 11 8	
[1,231 19 0]			1,263 14 2
	Leicester and Leicestershire Fund, 1933,		
	Investments (see Income and Expenditure Account, No. 6)	1,000 0 0	
	Cash at bank	74 9 2	
[1,040 5 0]			1,074 9 2
	Property Rehabilitation Fund		
	Investment (See Income and Expenditure Account, No. 7)		
	Cash at bank		
[144 0 0]			– – –
	Radford Mather Lecture Fund		
	Investment (see Income and Expenditure Account, No. 8)	250 0 0	
	Cash at bank	44 7 3	
[286 17 11]			294 7 3
	Mrs. E. M. Musgrave's Legacy		
	(See Income and Expenditure Account, No. 9)		
	Cash at bank		75 0 0
[150 0 0]			
	Arthur Haydock Bequest		
	Investment (see Income and Expenditure Account, No. 10)	2,215 12 0	
	Cash at bank	74 19 7	
[2,233 17 9]			2,290 11 7
	Cash at bank		100 0 0
[Nil]			
	Down House		
	Investments (see Income and Expenditure Account, No. 11)	21,296 9 5	
	Sundry debtors	10 4 11	
	Catalogues in stock, at cost	74 14 10	
	Cash at bank, Nil (see opposite)	– – –	
	Cash in hand	19 0 10	
	Excess of Expenditure over Income for the year . . . 474 12 3		
	Less Balance of Suspense Account from previous year . . . 181 15 5		
		292 16 10	
[21,542 5 6]			21,693 6 10
[88,204 4 11]			88,065 5 6

We have examined the foregoing Account with the Books and Vouchers and certify the same to be correct. We have also verified the Balance at the Bankers and the Investments, and have inspected the Deeds of Down House.

Approved :
EZER GRIFFITHS
ROBERT S. WHIPPLE } *Auditors.*

W. B. KEEN & CO., *Chartered Accountants*,
Finsbury Circus House, E.C. 2
3rd July, 1947

INCOME AND EXPENDITURE ACCOUNTS FOR THE YEAR ENDED 31st MARCH, 1947

No. 1. General Income and Expenditure

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
Investments at cost :		
£3,886 8s. 2d. Consolidated 2½ per cent. Stock (Inscribed)		2,901 3 0
£1,252 16s. 2d. Consolidated 2½ per cent. Stock (Registered)		1,000 0 0
£3,268 19s. 0d. 3 per cent. Savings Bonds 1955/65		3,268 19 0
£1,000 0s. 0d. 3 per cent. Savings Bonds 1960/70		1,000 0 0
£18,300 0s. 0d. 3 per cent. Savings Bonds, 1965/75		18,998 11 9
£879 14s. 9d. Great Indian Peninsula Railway 'B' Annuity, £43		827 15 0
£52 12s. 7d. 3½ per cent. War Stock (Post Office issue)		54 5 2
£7,370 19s. 6d. 3½ per cent. War Stock		7,482 10 9
£6,368 15s. 7d. 3½ per cent. Conversion Stock		5,304 8 11
£4,184 18s. 2d. 2½ per cent. Treasury Stock, 1975 or after		4,184 18 2
£1,000 0s. 0d. 4 per cent. Funding Loan Stock, 1960/90		1,170 0 0
£100 0s. 0d. 5 per cent. Great Western Railway Consolidated Preference Stock		125 0 0
£454 11s. 6d. 3 per cent. London County Consolidated Stock, 1956/61		462 2 0
£981 10s. 0d. 4 per cent. Commonwealth of Australia Stock 1955/70		1,000 0 0
[*Value of stocks at 31/3/46, £53,753 11s. 6d.*]	(Value at 31/3/47, £52,285 4s. 8d.)	
[*48,468 1 2*]		£47,779 13 9
Cash at bank and in hand		£717 10 8

EXPENDITURE

		£ s. d.	£ s. d.
To Heat, Lighting and Power			35 0 11
„ Stationery			232 17 9
„ Rent			1 0 0
„ Postages			160 7 9
„ Telephone			24 4 6
„ Insurances			15 10 1
„ Travelling expenses			226 17 0
„ Audit			42 0 0
„ Subscription to Parliamentary and Scientific Committee			10 10 0
„ Hire of meeting rooms, etc.			53 4 0
„ Reporting of Conferences, and copying, etc., by outside offices			94 11 0
„ Lift Inspection and Repairs			9 17 7
„ General expenses			54 2 1
„ Salaries, wages, pensions and National Insurance			2,195 19 7
„ Printing, etc.—			
"The Advancement of Science"		756 5 11	
Miscellaneous		146 6 3	
			902 12 2
„ Payments to authors for contributions to "The Advancement of Science"			21 0 0
„ Alexander Pedler Lecture, 1946 :			
Lecture fee		10 10 0	
Contribution to cost of printing by S.E. Union of Scientific Societies		8 0 0	
			18 10 0
„ Luncheon and Receptions in connection with Annual Meeting, 1946 (excluding Printing £44 6s. 10d., and Postage estimated at £25, included under "Printing" and "Postage," above)		521 12 0	
Less Contributions		163 12 6	
			357 19 6
[*3,574 4 1*]			4,456 3 11
„ *Balance, being excess of Income over Expenditure for the year*			– – –
[*110 15 4*]			
[*3,684 19 5*			£4,456 3 11

INCOME

		£ s. d.	£ s. d.
By Annual Membership subscriptions		570 8 0	
„ Corporate, Ditto		73 10 0	
„ Associateship subscriptions		193 8 11	
			837 6 11
„ Life Compositions : amount transferred on expiry of membership			66 0 0
„ Donations		105 5 0	
Less Gift for research in memory of Miss J. R. Corcoran, transferred to balance sheet		100 0 0	
			5 5 0
„ Sale of Publications		390 6 3	
Less amount transferred to Mathematical Tables Fund		43 3 6	
			347 2 9
„ Royal Society : grant from Parliamentary Grant in aid of Scientific publications			500 0 0
„ Advertisements in B.A. publications			169 16 0
„ Income Tax recovered to 31st March, 1946			39 14 10
„ Interest on Investments			1,259 16 9
„ Balance of Yarrow Fund transferred *			911 1 3
[*3,684 19 5*]			4,136 2 9
By Balance being excess of Expenditure over Income for the year, transferred to Contingency Fund			320 1 2
[– – –]			
[*3,684 19 5*]			£4,456 3 11

* The late Sir Alfred Yarrow made a gift of £10,000 to the Association in 1926 and attached the condition that the whole amount, capital as well as interest, should be expended within approximately twenty years. The balance now transferred to the credit of the Income and Expenditure Account exhausts this gift.

The expenses of a meeting of tribute to the late Mr. H. G. Wells, which was held at the Royal Institution on October 30, 1946, were defrayed by members of his family.

No. 2. Caird Fund

The unconditional gift of Sir James Caird, in 1912, administered by the Council in accordance with recommendations adopted by the General Committee in 1913.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
	Investments at cost :	
	£2,627 0s. 10d. 3 per cent. Savings Bonds 'A,' 1960/70	2,627 0 10
	£2,100 0s. 0d. London Midland and Scottish Railway 4 per cent. Preference Stock	2,190 4 3
	£2,000 0s. 0d. Southern Railway 5 per cent. Preference Stock	2,594 17 3
	£2,716 16s. 6d. 3½ per cent. War Loan Inscribed Stock	2,516 15 5
	[*Value of stocks at 31/3/46, £9,421 13s. 3d.*] (Value at 31/3/47, £9,725 8s. 11d.)	
[*9,928 17 9*]		£9,928 17 9
	Cash at bank	£436 6 10

EXPENDITURE

	£ s. d.
To Grants (see Schedule) [*130 0 0*]	597 1 9
„ Balance, being excess of Income over Expenditure for the year [*227 17 10*]	– – –
[*357 17 10*]	£597 1 9

Grants authorised, not yet drawn :—

Mathematical Tables	77 9 9
Zoological Record	50 0 0
Seismology	100 0 0
[*380 0 0*]	£227 9 9

INCOME

	£ s. d.
By Dividends and Interest	275 1 10
„ Income Tax recovered [*357 17 10*]	92 0 0
	367 1 10
By Balance, being excess of Expenditure over Income for the year – – –	229 19 11
[*357 17 10*]	£597 1 9

No. 3. Cunningham Bequest

A legacy received by the Association in 1929 in trust under the will of Lt.-Col. A. J. C. Cunningham, for the preparation of new mathematical tables in the theory of numbers ; administered by the Council.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
	Investments at cost :	
	£1,187 6s. 10d. Consolidated 2½ per cent. Stock (Inscribed)	653 0 9
	£178 16s. 5d. Consolidated 2½ per cent. Stock (Registered)	150 0 0
	£300 0s. 0d. Port of London 3½ per cent. Stock 1949/99	216 0 0
	£737 2s. 10d. 2½ per cent. Treasury Stock, 1975 or after	737 2 10
	[*Value of stocks at 31/3/46, £2,318 13s. 2d.*] (Value at 31/3/47, £2,315 6s. 9d.	
[*1,390 12 4*]		£1,756 3 7
	Cash at bank	175 12 7

EXPENDITURE

	£ s. d.
To Grants [*4 12 0*]	– – –
To Balance, being excess of Income over Expenditure for the year [*58 16 4*]	66 11 9
[*63 8 4*]	£66 11 9

Grant authorised, not yet drawn :—

Mathematical Tables	£50 0 0
– – –	£50 0 0

INCOME

	£ s. d.
By Dividends and Interest	60 4 5
„ Income Tax recovered	6 7 4
[*63 8 4*]	£66 11 9

No. 4. Toronto University Presentation Fund

A fund voluntarily subscribed by members present at the Toronto Meeting in 1924. From the income a presentation of two bronze medals each year is made, together with presents of books, to selected students in pure and applied science respectively.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
	Investments at cost :	
	£175 0s. 0d. 3½ per cent. War Stock	178 11 4
	[*Value of stock at 31/3/46, £185 1s. 3d.*] (Value at 31/3/47, £186 7s. 6d.	
[*£178 11s. 4d.*]		£178 11 4
	Cash at bank	£35 0 0

EXPENDITURE

	£ s. d.
To Balance, being Income for the year	6 2 6
[*6 2 6*]	£6 2 6

INCOME

	£ s. d.
By Interest	6 2 6
[*6 2 6*]	£6 2 6

NOTE:—Owing to the war, the Medals and Prizes awarded for the years 1942 onwards were not presented. Since the period covered by these accounts they have been sent to Toronto for distribution.

No. 5. Bernard Hobson Fund

The bequest of Mr. Bernard Hobson, 1933; the income to be applied to the promotion of geological research; administered by the Council.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
	Investments at cost :	
	£50 0s. 0d. 4 per cent. Victory Bonds	55 10 5
	£601 9s. 0d. 2½ per cent. Treasury Stock, 1975 or after	601 9 0
	£416 0s. 11d. 3½ per cent. War Stock (Inscribed)	436 3 1
	£178 16s. 4d. Consolidated 2½ per cent. Stock (Registered)	150 0 0
[*Value of stocks at 31/3/46, £1,265 2s. 2d.*]	(Value at 31/3/47, £1,250 4s. 11d.)	
[*1,150 0 0*]		£1,243 2 6
	Cash at bank	£20 11 8

EXPENDITURE	£ s. d.	INCOME	£ s. d.
To Grant (see Schedule)	100 0 0	By Interest	37 10 4
[– – –]		[*35 14 6*]	
To Balance, being Excess of Income over Expenditure for the year	– – –	„ Income Tax recovered	1 2 4
[*35 14 6*]		[– – –]	
		By Balance, being Excess of Expenditure over Income for the year	61 7 4
[*35 14 6*]	£100 0 0	[*35 14 6*]	£100 0 0

Grants authorised, not yet drawn :—
Kent's Cavern . . £5 0 0

[*6 0 0*] £5 0 0

No. 6. Leicester and Leicestershire Fund, 1933

The unexpended balance of the local fund for the Leicester Meeting in 1933, presented to the Association, the interest to be used in assisting by scholarships or otherwise students working for the advancement of science; administered by the Council.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
	Investments at cost :	
	£487 2s. 11d. 3½ per cent. Conversion Stock	500 0 0
	£490 5s. 11d. 3½ per cent. War Stock	500 0 0
[*Value of stocks at 31/3/46, £1,048 6s. 4d.*]	(Value at 31/3/47, £1,062 18s. 1d.)	
[*1,000 0 0*]		£1,000 0 0
	Cash at bank	£74 9 2

EXPENDITURE	£ s. d.	INCOME	£ s. d.
To Balance, being Income for the year	34 4 2	By Interest	34 4 2
[*34 4 2*]	£34 4 2	[*34 4 2*]	£34 4 2

No. 7. Property Rehabilitation Fund (incorporating balance of the Herbert Spencer Bequest Fund)

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

EXPENDITURE	£ s. d.	INCOME	£ s. d.
To General Income and Expenditure Account	– – –	By Interest	3 5 2
[*3 0 0*]		[*11 18 10*]	
„ Down House Income and Expenditure Account : Cost of Repairs at Down House	152 15 1	„ Balance, being Excess of Expenditure over Income for the year	149 9 11
[*204 14 4*]		[*195 15 6*]	
[*207 14 4*]	£152 15 1	[*207 14 4*]	£152 15 1

No. 8. Radford Mather Lecture Fund

A gift of £250 received from Mr. G. Radford Mather in 1936 to establish a Fund, the income therefrom to be devoted to meeting the expense of triennial Lectures on Recent Advances in Science and their relation to the Welfare of the Community.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
Investment at cost :		
£248 17*s.* 8*d.* 3 per cent. London County Consolidated Stock, 1956/61		250 0 0
[*Value of stock at 31/3/46, £258 16s. 9d.*]	(Value at 31/3/46, £262 11*s.* 4*d.*)	
[*250 0 0*]		£250 0 0
Cash at bank		£44 7 3

EXPENDITURE	£ s. d.	INCOME	£ s. d.
To Balance, being Income for the year . .	7 9 4	By Interest	7 9 4
[*7 9 4*]	£7 9 4	[*7 9 4*]	£7 9 4

No. 9. Mrs. E. M. Musgrave's Legacy

A legacy of £300, received in 1944, "for the development of biological research, with special reference to the investigation of the fresh water fauna of English lakes and to the grant of small sums to young research workers specially in need of financial assistance."

Cash at bank £75

EXPENDITURE	£ s. d.	INCOME	£ s. d.
To Grant (see Schedule)	75 0 0	By Balance, being Expenditure for the year .	75 0 0
[*75 0 0*]	£75 0 0	[*75 0 0*]	£75 0 0

No. 10. Arthur Haydock Bequest

A bequest received in 1945 "for the purpose of original investigation of problems relating to either or both of Geology or Botany as may be determined by the governing body of the British Association."

		£ s. d.
Investment, as received :		
£2,090 4*s.* 0*d.* 3½ per cent. Conversion Stock (Registered)		2,215 12 0
[*Value of Stock at 31/3/46, £2,273 1s. 10d.*]	(Value at 31/3//47, £2,320 2*s.* 5*d.*	
[*2,215 12 0*]		£2,215 12 0
Cash at bank		£74 19 7

EXPENDITURE	£ s. d.	INCOME	£ s. d.
To Balance, being Income for the year . .	56 13 10	By Interest	38 8 1
		„ Income Tax recovered	18 5 9
[*18 5 9*]	£56 13 10	[*18 5 9*]	£56 18 10

No. 11. Down House

In response to an appeal made in 1927 by Sir Arthur Keith, F.R.S., then President of the British Association, Mr. (later Sir) Buckston Browne, F.R.C.S., acquired the property of Down House, formerly the home of Darwin, and transferred it with an endowment of £20,000 to the Association as a gift to be held as a memorial to Darwin in custody for the nation.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
Investments at cost :		
£3,000 Fishguard and Rosslare Railway and Harbours 3½ per cent. Guaranteed Preference Stock		2,139 17 3
£3,340 Great Western Railway 5 per cent. Consolidated Guaranteed Stock		3,436 7 5
£2,500 Birkenhead Railway 4 per cent. Consolidated Stock		2,013 9 9
£7,944 2*s.* 4*d.* Consolidated 2½ per cent. Stock (Inscribed)		6,206 15 0
£5,971 16*s.* 11*d.* Consolidated 2½ per cent. Stock (Registered)		5,000 0 0
£2,444 15*s.* 10*d.* 3 per cent. Redemption Stock, 1986/96 (Registered)		2,500 0 0
[*Value of stocks at 31/3/46, £25,284 17 10d.*]	(Value at 31/3/47, £26,026 2*s.* 5*d.*)	
[*21,296 9 5*]		£21,296 9 5
Cash *overdrawn* at bank		382 19 9
Cash in hand		19 0 10

No. 11. Down House (*continued*)

EXPENDITURE	£ s. d.	INCOME	£ s. d.
To Wages of Staff	1,008 2 9	By Rents receivable	114 14 6
„ Rates, Insurance, etc.	93 5 4	„ Income Tax recovered	348 6 6
„ Electricity	69 11 11	„ Dividends and Interest	538 15 1
„ Fuel, etc.	98 1 2	„ Sale of catalogues, postcards and photographs	17 14 10
„ Drainage	30 13 5	„ Donations received	2 9 9
„ Water	18 10 9	„ Transfer from Property Rehabilitation Fund	152 15 1
„ Repairs and Renewals	205 5 5	[*1,339 15 7*]	1,174 15 6
„ Land and Garden: materials and maintenance	54 4 0	„ Balance, being Excess of Expenditure over income for the year	474 12 1
„ Donations to village institutions	5 5 0	[*291 13 1*]	
„ Household requisites, etc.	14 14 6		
„ Furniture and fittings (including water heater in gardener's cottage)	28 16 9		
„ Carriage	2 9		
„ Printing, postage, telephone, stationery	18 10 3		
„ Legal advice	4 4 0		
[*1,631 8 8*]	£1,649 8 0	[*1,631 8 8*]	1,649 8 6

Note.—Further expenditure estimated at £260 has been authorised for work in connection with the hot water system and radiators at Down House.

Schedule of Grants Paid to Research Committees, etc.

during the financial year to March 31, 1947

NOTE.—The year indicated in brackets after the title of each committee is that of its original appointment, and the sum, if any, is that previously expended out of grants by the Association.

	£ s. d.	£ s. d.
1. Paid out of the Caird Fund (1912)		
Plymouth Laboratory (1886: £1,798 10*s.* 8*d.*)	50 0 0	
Zoological Record (1923: £1,085)	50 0 0	
Seismological Investigations (1895: £5,420 14*s.* 8*d.*)	100 0 0	
Naples Zoological Station (1876: £1,100)	50 0 0	
Mathematical Tables*	347 1 9	
		597 1 9
2. Paid out of Mrs. E. M. Musgrave's Legacy (1944)		
Freshwater Biological Station (1930: £1,162 15*s.* 11*d.*)		75 0 0
3. Paid out of the Bernard Hobson Fund (1933)		
Geological Photographs (1889: £101 19*s.* 11*d.*)		100 0 0
		£772 1 9

*Mathematical Tables (1913)

Total grants paid to March 31, 1947:—

	£ s. d.	£ s. d.
From Cunningham Bequest	2,840 10 11	
„ Caird Fund	1,644 9 11	
„ Mathematical Tables Fund	192 16 0	
„ General Fund	415 17 6	
„ Royal Society Grant (1933)	50 0 0	
	£5,143 14 4	
Amount recovered by sale of tables, etc.:	£ s. d.	
As last year	806 2 6	
Add for year to 31/3/47	125 11 10	
	931 14 4	
	£4,212 0 0	

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